SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

1955 Literature Review, Part II—Research Committee

Industrial Wastes—Water Pollution

Buffalo Sludge Facilities—Crane et al.

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JUNE, 1956—VOL. 28, No. 6

Make Plans to Attend

29TH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

CALIFORNIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

STATLER HOTEL

LOS ANGELES, CALIFORNIA

October 8-11, 1956

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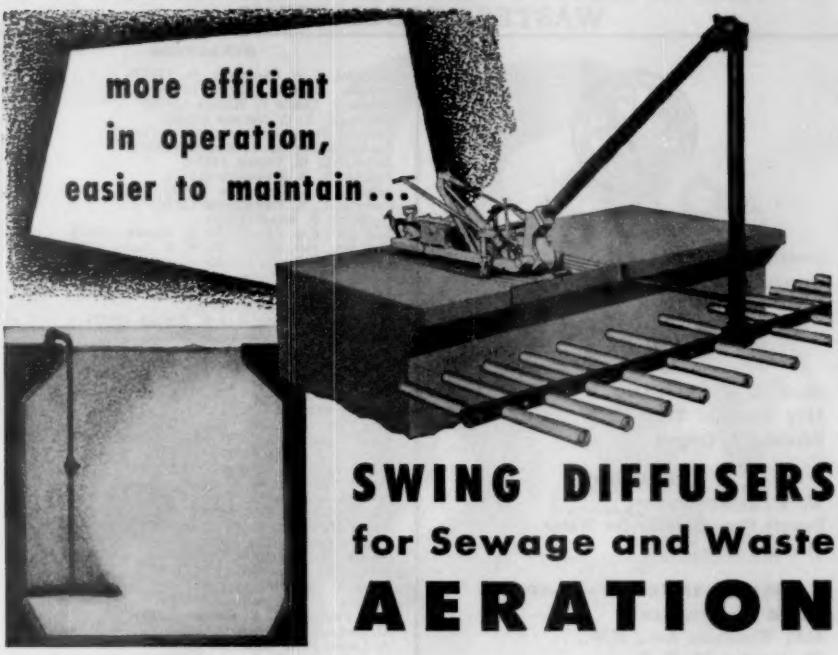

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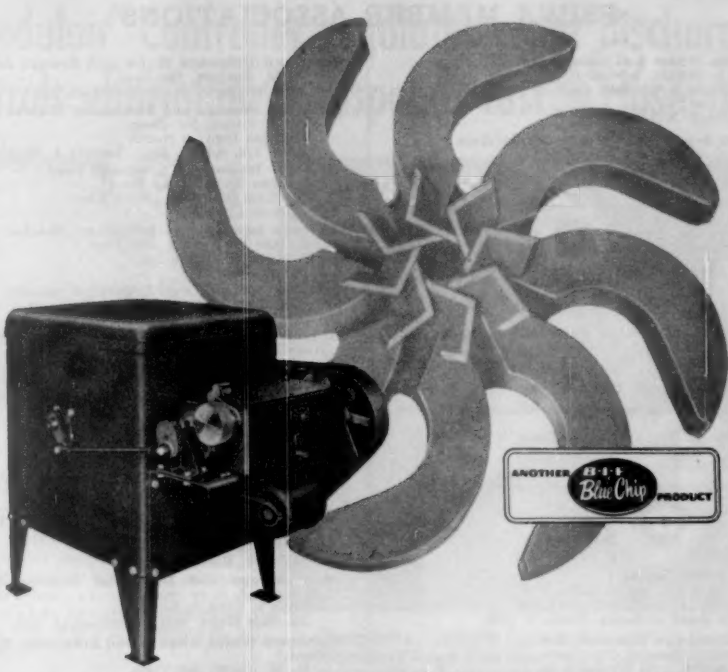

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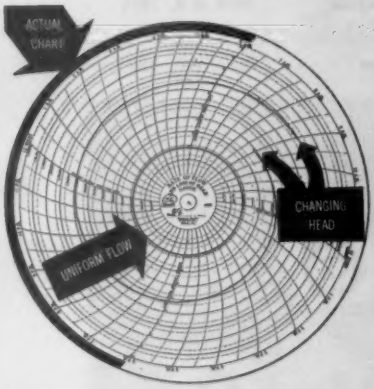
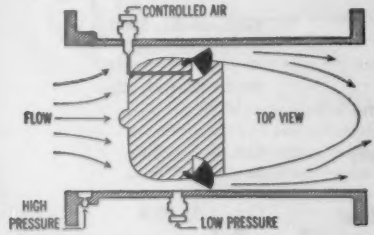
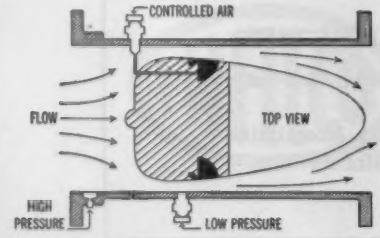


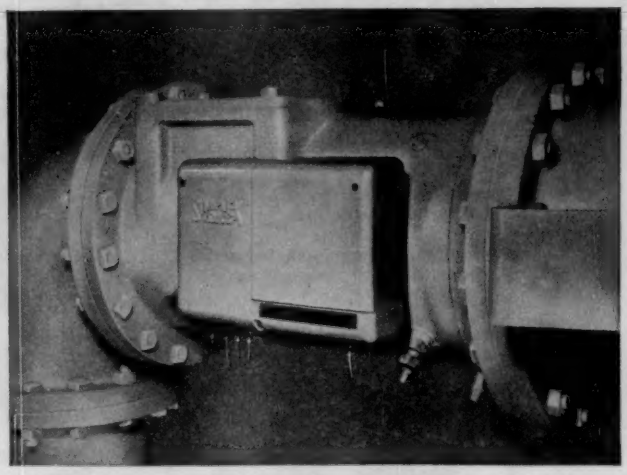
Here's proof that the new Simplex Modulair Controller responds instantly to changes in operating head . . . automatically holds flow at desired rate. Chart from Modulair installation shows head increasing 75% while flow forms almost perfect circle.



How Modulair works! Pipe-like casting with annular Venturi throat houses streamlined inner body with corded-rubber modulator (black) that expands and contracts pneumatically to control flow. When operating head rises, modulator expands automatically to restrict flow to set rate.



When operating head falls, flow tends to decrease—changing the Venturi differential. Sensitive Modulair compensates immediately. Modulator contracts—automatically keeps flow at rate desired.



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Accuracy! In 4 years of field performance, Modulair shows an accuracy in control that exceeds today's most exacting demands. It brings you sensitive, accurate flow control under wide ranges of operating head. And is tight-closing—eliminating need for separate shut-off valves.

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Ohio Sewage and Industrial Wastes Treatment Conference	Hotel Carter Cleveland, Ohio	June 13–15, 1956
Institute of Sewage Purification	Harrogate, England	June 18–22, 1956
Central States Sewage and Industrial Wastes Assn.	Northland Hotel Green Bay, Wis.	June 20–22, 1956
Pennsylvania Sewage and Industrial Wastes Assn.	Pennsylvania State University University Park, Pa.	Aug. 29–31, 1956
Iowa Sewage and Industrial Wastes Assn.	P. M. Park Clear Lake, Iowa	Sept. 12–14, 1956
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Hotel Patten Chattanooga, Tenn.	Sept. 17–19, 1956
Georgia Water and Sewage Assn.	Hightower Textile Bldg. Georgia Inst. of Technology, Atlanta, Ga.	Sept. 19–21, 1956
South Dakota Water and Sewage Works Conference	Aberdeen, S. D.	Sept. 19–21, 1956
Missouri Water and Sewerage Conference	Hotel Governor Jefferson City, Mo.	Sept. 30–Oct. 2, 1956
Abwassertechnische Vereinigung	Dusseldorf, Germany	Oct. 3–5, 1956
North Dakota Water and Sewage Works Conference	Lewis and Clark Hotel Mandan, N. D.	Oct. 3–5, 1956
Pacific Northwest Sewage and Industrial Wastes Assn.	Boise, Idaho	Oct. 4–6, 1956
Canadian Institute on Sewage and Sanitation	Prince Edward Hotel Windsor, Ontario	Oct. 29–31, 1956

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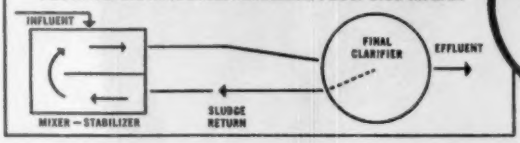

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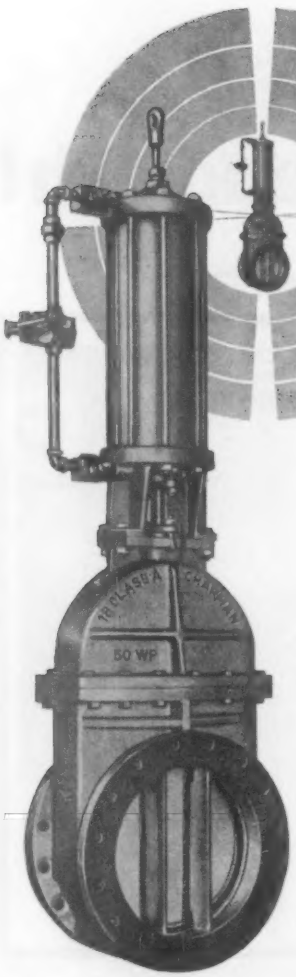

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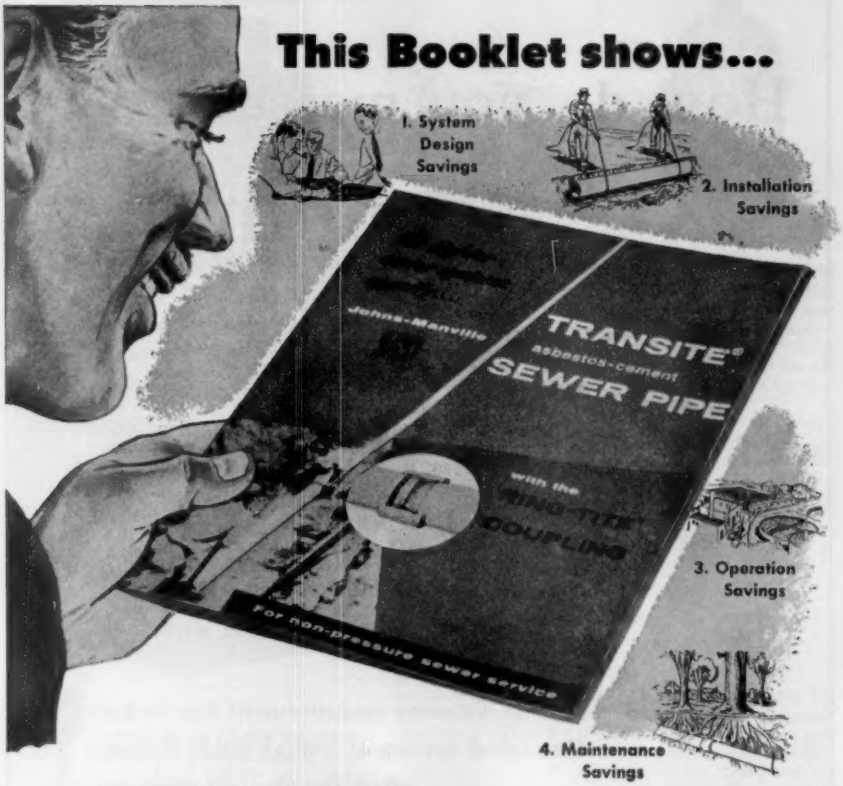

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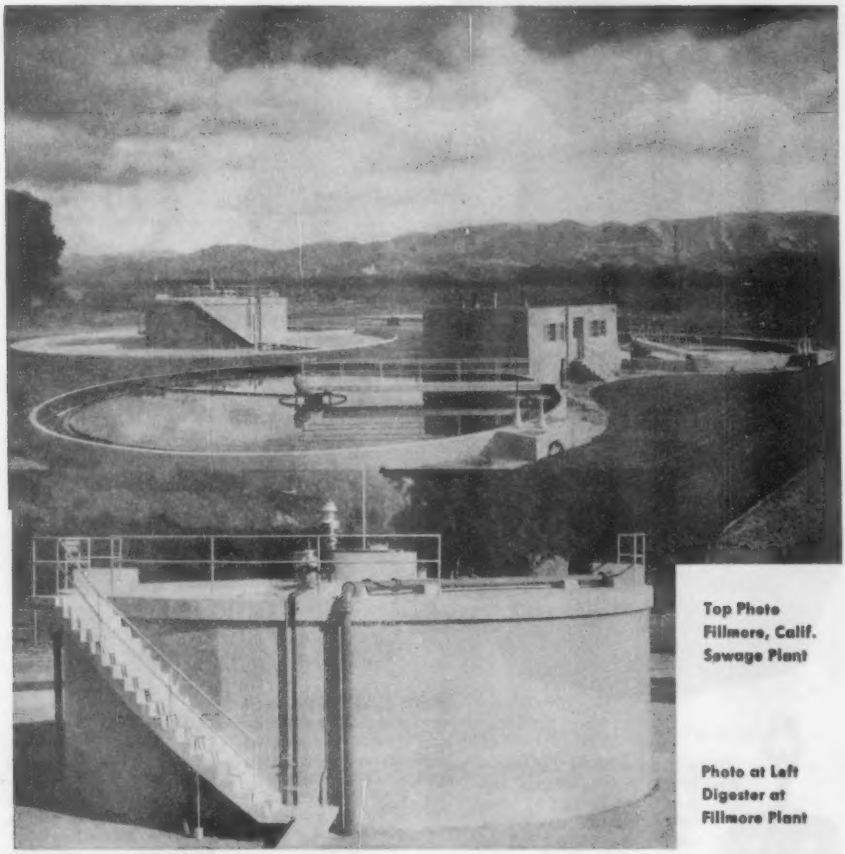

Top Photo
Fillmore, Calif.
Sewage Plant

Photo at Left
Digester at
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Glass graduate at left shows waste as it flows into settling tank at chemical plant. Mound of sludge filter cake in center represents solids taken from liquid (right) before discharge into sewerage system.

LINK-BELT Circuline Collector concentrates sludge fast in treating corrosive waste at Ohio chemical plant

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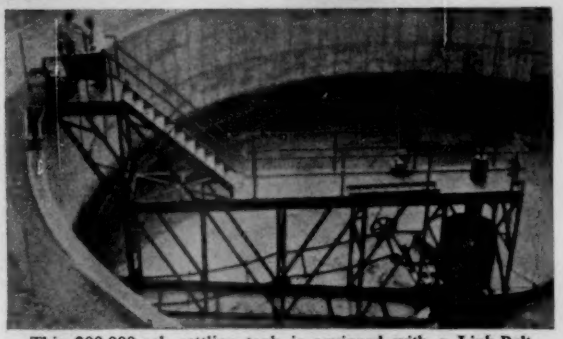

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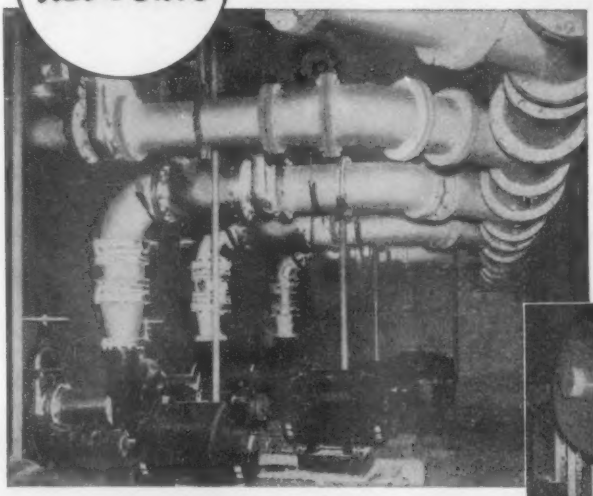

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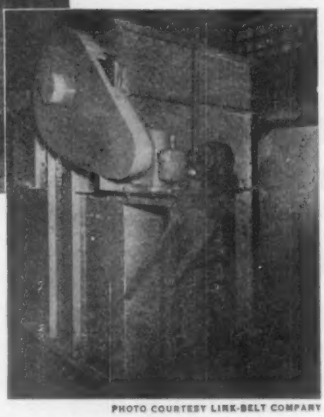

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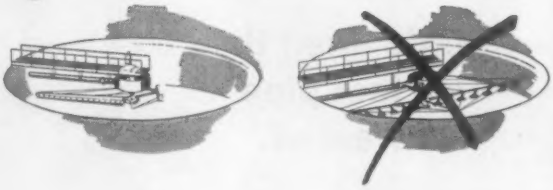

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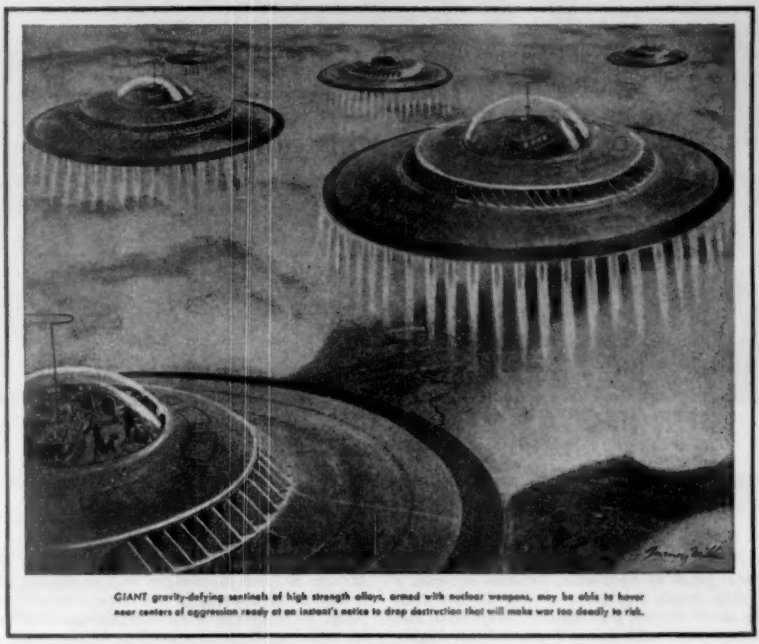

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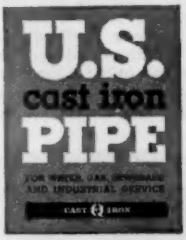

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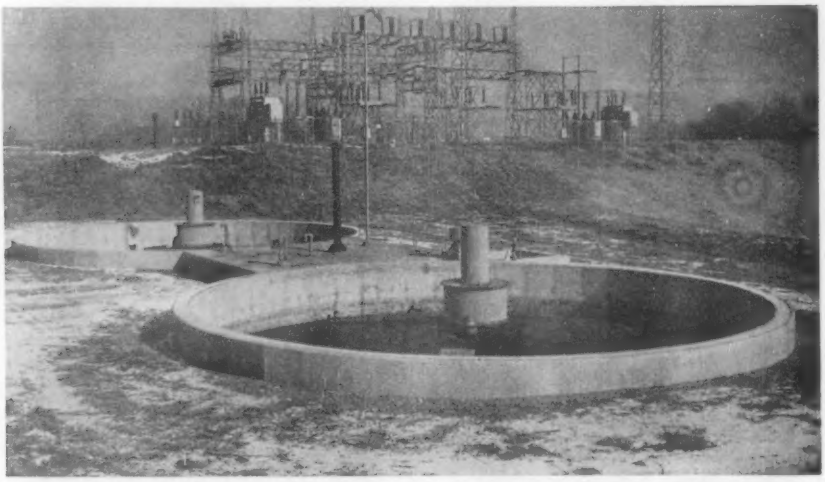

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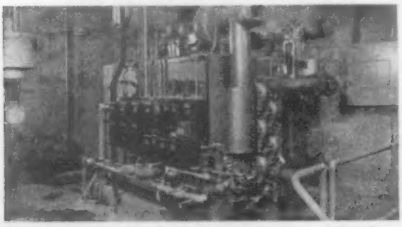

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 28 **June, 1956** **Number 6**

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Ralph E. Fuhrman, *Editor*, 4435 Wisconsin Ave., N.W., Washington 16, D. C.
Dr. F. W. Mohlman, *Advisory Editor* Donald P. Schiesswohl, *Assistant Editor*
Mrs. Elizabeth Quick, *Editorial Assistant*

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Aerial view of the Ada plant taken in 1954 shortly after starting up. Clariflocculator unit at left. Consulting Engineer: Ralph W. Delaney, Ada, Oklahoma.

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LOW RATE TRICKLING FLOWSHEET

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1955 Literature Review

A CRITICAL REVIEW OF THE LITERATURE OF 1955 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

By H. Heukelekian, *Chairman*, H. E. Orford, *Vice-Chairman*, H. Amberg, B. Berger, D. E. Bloodgood, W. E. Dobbins, G. P. Edwards, M. B. Ettinger, T. deS Furman, I. Gellman, A. S. Goldin, A. E. Griffin, C. Henderson, A. Hirsch, R. D. Hoak, R. S. Ingols, P. W. Kabler, M. Katz, R. P. Logan, R. Manganelli, P. H. McGauhey, W. A. Moore, G. Paine, R. C. Palange, C. M. Palmer, G. A. Rohlich, L. R. Setter, C. M. Tarzwell, G. H. Teletzke, W. W. Towne, H. A. Trebler, E. C. Tsivoglou, J. W. Wiseman and R. L. Woodward.

Committee on Research, Section A, Federation of Sewage and Industrial Wastes Associations

This is the second of two sections of the review. The first section, dealing with analytical methods, sewage and radioactivity, was published in the May, 1956 issue of This Journal.

INDUSTRIAL WASTES

Canning Wastes

Reports from laboratory and small-scale pilot-plant studies continue to indicate that a high degree of treatment can be obtained if the cost of the trickling filter or activated sludge plant can be tolerated and some way can be found to reduce the lag period for attaining reasonable efficiency. Dougherty *et al.* (39) report on the treatment of citrus wastes with activated sludge in the laboratory. Leete *et al.* (82) report on the treatment of pea-blancher waste disposal by trickling filters. Olivier and Dunstan (98) have shown that the strong pea-blancher waste (1.9 per cent B.O.D.) can be digested with digested sewage sludge with a 9-day cycle (detention). Wakefield *et al.* (144) have reviewed the status of various sanitary engineering techniques for treating citrus wastes.

Dunstan and Lunsford (40) have reported on disposal of strong wastes on experimental plots in which enough organic matter was added to kill the crops on some plots. More waste could be sprayed on a plot with a cover crop than on one without a crop. Grasses were a better crop than alfalfa. In a favorable report on irrigating wastes, Bell (18) indicates that sufficient hay was harvested and sold to cover the cost of the operation. Application of the wastes was made at the rate of 0.3 to 0.6 in. per day with a total application up to 60 in. per season.

The broad field disposal of beet sugar wastes has been reported in detail by Porges and Hopkins (105) as successful in eliminating suspended

solids and in reducing the B.O.D. Problems in the operation of lagoons in the treatment of wastes from a sugar factory are reported by Beeckmans and Beaujean (17). When three lagoons are operated in series, the first acts like a septic tank unless chlorine is applied.

Many of the liquid waste problems of the citrus industry would be solved by a controlled air composting of its solids wastes according to Bondi (23). The composting of the solid wastes from the canning of many of the vegetables is also recommended. Air flotation is recommended for reducing the B.O.D. load of canning waste prior to discharge to a city sewer (10) when the B.O.D. load determines the sewer charge.

Additional References

Grunewald, A., "Treatment of Potato (Starch Manufacture) Process Waters and Industrial Recovery of Protein." *Die Starke*, **6**, 182 (1954); *Chem. Abs.*, **49**, 2103 (1955).

Leclerc, E., "The Urgent Problem of Protection of River Waters Polluted by the Waste Waters of Sugar Factories." *Sucr. Belge* (Belgium), **74**, 119 (1954); *Chem. Abs.*, 2765 (1955).

Dairy Wastes

Several surveys of the entire dairy waste problem have appeared. Woolings (150) discusses the various treatment methods and concludes that under the conditions in Ontario, Can., the most practical method, particularly for small milk processing plants, is still anaerobic digestion in septic tanks. In one cheese processing plant the treatment unit consists of a grease trap (2-hr. retention), a digestion tank (six days retention) and a lagoon. Total capacity is 1,000 g.p.d. Overall B.O.D. reduction was 67 per cent, total solids reduction was 71 per cent. The lagoon effluent had a B.O.D. of 1,140 p.p.m. which might not be satisfactory under many conditions. Also discussed was broad irrigation at Gravenhurst, which has been operating successfully for four years. No trouble is experienced with odors, insects, or freezing in winter. The highly alkaline waste has a volume of 2,400 g.p.d. in the summer. The field has 12 trenches, each 90 to 100 ft. long. Average trench width in the sandy soil is 12 in. A high-rate recirculating trickling filter installation at Jarvis reportedly is doing a good job. Average waste flow is 1,590 g.p.d.; holding tank capacity is 1,125 gal.; filter area is 0.18 acre; filter volume is 16 cu. yd.; recirculation ratio is 10:1; the rate of application is 9.7 m.g.a.d.; the settling period is 4.8 hr.; the raw waste B.O.D. is 847 p.p.m.; effluent B.O.D. is 70 p.p.m., and the B.O.D. loading is 0.8 lb. per cubic yard per day. This trickling filter operates only nine months each year. Sludge is pumped at irregular intervals to an abandoned septic tank. The author states that the relatively high construction cost, difficult winter operation and uncertain sludge disposal apparently have discouraged trickling filter construction in Ontario. (There are only four.) A successful spray irrigation installation at a cheese plant at Berwick is described (6), in which two high-pressure spray nozzles are used alternately.

Botha (24) presented a complete report on a survey of South African conditions. Instructions are given for waste saving and for broad irrigation under South African conditions and details are presented on laboratory experimental work with trickling filters, comparing results when treating diluted whole milk, buttermilk, whey and a combination of all three. As might be expected, because of its fat content, whole milk required more trickling filter capacity than the other products for the same O.A. removal. (O.A. is oxygen absorbed from permanganate in 4 hr. at 26.7°C. For dairy waste the values appear to be about 1/10 of the corresponding 5-day B.O.D.

values.) Botha concludes that alternating, double-filtration on biological filters is still the best and most reliable treatment if a very high-grade effluent at low operating cost is desired, but that construction costs are too high for most milk plants. Consequently, whenever possible, waste should either be sent to city disposal plants or used for broad irrigation. He does not discuss spray irrigation although it should fit South African conditions well.

Muers (93) has again reviewed the dairy waste and disposal problem in Great Britain with stress on waste saving. Spray irrigation appears not to have been successful and the activated sludge type of treatment is too sensitive to overloads. The low-rate, double, alternating-flow trickling filter systems are undoubtedly economical to operate even if the cost of construction under most conditions is considered too high. These filters are capable of producing the high-grade effluents required under British conditions.

Cantinieaux (30) discusses conditions in Belgium. He describes two dairy waste treatment plants. One uses two-stage trickling filters with primary and secondary clarifiers and recirculation; the other uses activated sludge. Both produced B.O.D. reductions in excess of 90 per cent.

During recent years, several interesting reviews (108) (120) (121) (123) (134) (137) have presented the German approach to dairy waste disposal. There is agreement on the following: (a) waste saving is very important and strong by-products should not be discharged to the sewers; (b) wherever possible, public sewers and treatment plants should be used in preference to private facilities; (c) spray irrigation is the preferred treatment where suitable land is available; (d) both trickling filters and activated sludge units are satisfactory, but should only be used where public facilities or spray irrigation are not possible. This agrees with experience in this country and in Holland.

In special cases other disposal methods may be advantageous. For instance, fish ponds are used successfully both in Germany (121) (134) and in Czechoslovakia (109). According to Struve (134), the waste should be well strained and mixed (1:15) with well-aerated water before entering the ponds. The area needed is 2.5 to 12.5 acre for each 4,000 g.p.d. of flow. Pytlik and Svec (109) studied the use of fish ponds for disposal of waste from seven dairies in Czechoslovakia and found that the area of a pond, 3 ft. in depth, which is required for dairies which occasionally waste whey is seven acres for every 10,000 lb. of milk processed daily. If no whey is dumped, four acres will suffice. The wastes are strained to remove large particles and discharged to the pond through multiple inlets. Occasionally, slaked lime is added at the rate of about 1,700 lb. per acre per year. It is difficult to understand why lime is needed, since lactic acid certainly should be oxidized to CO_2 under the conditions prevailing in large shallow ponds.

Tewes (137) points out that it is satisfactory to spray waste that contains up to 10 per cent whey. The area required is 25 acres for each 25,000 gal. of waste discharged per day. He states that if proper precautions are taken, there is no objection to spraying even in very cold weather. According to Hüdig (62), apparently the trend in Germany is not to use as small an area as possible, but to get maximum benefit from the waste, both for its irrigation and fertilizer value. A load of 10,000 g.p.d. on 12.5 acres is suggested. The farmers pay one-half the installation and operating costs which are more than returned in the increased yield of hay.

Schulz-Falkenhain (128) discusses spray irrigation with dairy waste and in another article (127) discusses the

possible risk of transmitting diseases by spray irrigation or other dairy waste treatment methods.

Huurneman (64)(65) reports on a two-year operation of spray irrigation at a dairy plant in Vorden. Cooling waters are segregated and discharged directly to a creek, while the floor wastes are collected in a pump pit outside the building. Eight vats of cheese and two churnings of butter (2,200 lb.) are produced daily, and about 30,000 lb. of whey are made into whey powder. The waste volume was reduced from 32,000 g.p.d to about 21,000 g.p.d. The wastes are sprayed on about 7.5 acres of grassland, giving an average spray coverage of 2.5 mm. per day or 15 mm. per week. The author believes that this amount of irrigation gives good waste disposal and maximum benefit to the pasture, and that under the particular conditions in this plant it is not advisable to increase the loading. Large spray nozzles delivering 120 g.p.m. each caused silting and sogginess, and were replaced with smaller nozzles (30 g.p.m.) which produce a much finer distribution and avoid sogginess. The nozzles are moved twice each day and there are no obnoxious odors under any weather conditions. However, it is very important that the entire system be thoroughly rinsed out with clean water (e.g. cooling water) at the end of each day's operation.

Hoover and associates (60) of the U. S. Department of Agriculture have calculated purification rates and actual oxidation rates on the basis of their experimental results previously reported. They conclude that for dairy waste the purification rate is about 10 times as fast as the oxidation rate. With good aeration and agitation in the presence of an ample volume of active sludge, the actual purification of the waste occurs in a short time and could be done in a relatively small tank; whereas the completion of the biological oxidation of the organic matter taken up by the floc requires a considerably longer period of time. Unfortunately, since the sludge volume in dairy practice is relatively large (often 50 per cent or more), the total aeration tank capacity is not greatly reduced by sludge regeneration in a separate tank or compartment. However, the settling ability of the sludge might be improved or foaming difficulties reduced.

Kountz (77)(78)(79) has given several additional papers on the activated sludge type of treatment using jet aerators and batch operation on which he reported in 1954. No analytical data have as yet been presented and his contention that discharge of excess sludge is never needed remains unproven.

According to Trebler and Harding (139)(140)(141), indications are that the sludge volume undoubtedly can be greatly reduced by prolonged aeration but that ultimately under plant conditions, some excess sludge has to be discharged either voluntarily or involuntarily through foaming or through suspended matter in the effluent.

Power (106) reported on a continuous flow, activated sludge type of dairy waste treatment plant in Massachusetts, using 24 size 4A ejectors for aeration. The jets receive both air and liquid under pressure. The original article contains some errors, but this review is based on corrected data supplied by the author. On one day of sampling, the waste flow was 17,300 gal.; air flow was 280 c.f.m. and the liquid circulation flow through the jets was 280 g.p.m. The average rate of effluent flow was 18 g.p.m. for 16 hr.; raw B.O.D. was 430 p.p.m. or 62 lb. per day; effluent B.O.D. was 15 p.p.m. or 2.2 lb. per day, or a reduction of 96.5 per cent; air was supplied at 4.5 c.f.m. per pound of B.O.D. which is high. No effort is made to remove excess sludge, but there is a considerable loss of light floc with the effluent. Periodic sludge return is used. In

spite of obvious overaeration, this plant apparently had no foaming difficulties. This is probably due to the long overflow weir in the aeration tank, which returns floating particles rich in surface-active compounds to the pump pit for recirculation through the jets, and to a high concentration of suspended solids.

Schulze (13)(125)(126) has continued the activated sludge type of treatment of cheese plant wastes using mechanical aerators to suck air, liquid and foam in through a hollow shaft. Apparently, he has succeeded in reducing power demand, but may have sacrificed some of the foam-killing ability of the regular Waldhof fermentor. However, he takes care of foam by covering the aeration tank and forcing the foam to overflow into the raw waste storage tank. Excess sludge is not handled by prolonged aeration; it is discharged daily to a sand bed. As in most other activated sludge type dairy waste plants, occasional troubles are encountered with a light floc in the effluent. The treatment plant handles 120 lb. of B.O.D. per day with 10 to 11 h.p., which is in line with some activated sludge type plants using suction jets; but is about double the power requirement for plants using pressure on both the air and liquid supplied to the jets.

Davy (35) reports the pretreatment of dairy waste by means of a high-rate recirculating trickling filter before discharge to a municipal treatment plant. With a loading of 3.64 lb. of B.O.D. per cubic yard, a 50 per cent B.O.D. reduction was obtained without settling. Information is not given concerning the presence or absence of odor or clogging troubles at this high loading.

Preuss (107) describes a patented German Ferrobion process which consists of adding a relatively small amount of iron salt to the waste ahead of a recirculating trickling filter. Approximately 22 to 26 lb. of coarse crystalline iron sulfate is added daily to 8,000 to 9,000 gal. of waste and then diluted to 18,000 gal. with cooling water. The amount of iron is insufficient to produce complete chemical precipitation. It is difficult to understand why iron would stimulate the microorganisms in the dairy waste, and any chemical catalytic effect seems improbable. Analytical data are given in terms of oxygen consumed (O.C.) from potassium permanganate solution rather than in B.O.D. The diluted waste shows 1,000 to 1,500 p.p.m. O.C. and the effluent less than 100 p.p.m. O.C. The trickling filter is 27 ft. in diameter and 9.8 ft. deep and contains 196 cu. yd. of rock (lava). The loading is about 0.7 to 1.1 lb. O.C. per cubic yard per day which, if the O.C. test is run as it is here, might mean 1.4 to 2.2 lb. B.O.D. per cu. yd. per day This is high but not excessive if the 100 p.p.m. O.C. in the effluent corresponds to 200 to 300 p.p.m. B.O.D. A regular high-rate recirculating trickling filter would probably give similar results without the addition of iron.

Brazis (27) Edmondson and Brazis (42) studied the effect of various bacteria cultures on dairy waste treated on a fill and draw basis in laboratory trickling filters with an application rate of 460 gal. per square foot per day. Three of the cultures tried were effective and continuous pH standardization was helpful.

Jonas (70) discusses the relative merit of various treatment methods and reports results by fermentation with *Oidium lactis* at 30°C. Lime is added to increase the pH to 10 and the precipitated material is filtered, dried and used for feed. The supernatant is diluted and the pH is adjusted to 8 and discharged. The B.O.D. reduction is 67 per cent.

Reinhold (112) reports laboratory experiments with anaerobic treatment of dairy waste. The supernatant liquid from a digestor used for producing gas from stable manure was

held at 30° C. and, after gas production was completed, milk was added periodicaly. During a 15-week experiment, 90 per cent B.O.D. reduction and limited sludge formation were obtained. The gas produced was burnable.

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Packinghouse Wastes

Uhlmann (142) described an activated sludge plant designed for treatment of wastes from the killing of 1,000 hog units per day. Sludge solids are digested and over-all B.O.D. reductions average 96 per cent. Reasons for building a separate treatment plant rather than paying sewer rental charges are discussed.

Schroepfer *et al.* (122) reviewed results of a four-year cooperative study of an anaerobic contact process producing 95 per cent B.O.D. reductions at loadings of 0.2 lb. of B.O.D. per cubic foot. Digester retention time is 12 hr. with degasification used for separation of sludge for recycling. Lower construction costs are indicated than for comparable trickling filter treatment. Process is believed to be rugged and well-suited for load fluctuations. Steffen (133) discussed the design of the first full-scale treatment plant using the anaerobic contact proc-

ess. Design details for the degasifier, sludge mixing, digester heating and sludge sedimentation equipment are given, as well as a discussion of the planned step-wise construction of the plant.

In order to reduce sewer rental charges, it is reported (11) that a packinghouse killing 1,000 cattle and 5,000 hogs per week installed a series of catch basins, alum feed and a flotation unit. The plant now recovers 10,000 lb. per week of marketable solids and fats besides saving $15,000 per year in sewer service charges.

A report (58) to the Auckland, New Zealand Drainage Board recommended high-rate anaerobic digestion for treatment of wastes at local packinghouses to be supplemented by aerobic treatment where needed. Reinson (113) described a French pilot-plant for treatment of packinghouse wastes which had a daily population equivalent load of 50,000 to 60,000.

Fermentation Industries

Pitts (104) discussed operating problems and results obtained at a treatment plant consisting of aeration basins and trickling filters for treatment of antibiotic fermentation wastes. Under normal conditions the plant receives 5,700 lb. of B.O.D. per day and produces in excess of 90 per cent B.O.D. reduction. Difficulty is experienced during winter months due to clogging of filter voids with film. Deterioration of slag filter media is also considered responsible for clogging of the beds.

Jones and Murdock (71) found wastes as strong as 55,000 p.p.m. B.O.D. resulting from production of grass silage. Seepage could be eliminated by drying the grass to 30 per cent solids or by covering silage to prevent leaching action caused by rain. Where seepage cannot be avoided, disposal on soil was considered the only practical solution.

Pharmaceutical and Chemical Wastes

Jenkins (68) summarized progress being made in reducing the volume of waste discharged from a chemical manufacturing plant to the Kanahwa River at South Charleston, S. C. Major effort has been in revising existing sewers to reduce the flow that will eventually be treated. A $100,000 trickling filter pilot-plant was put in operation two years ago. New processes are being carefully engineered to eliminate toxic materials. One such process involved $1 million additional expense for this purpose.

Two papers described disposal of organic chemical wastes by pumping into a deep underground brine strata in Michigan. In one case reported (1), wastes from synthetic antibiotic production are sand filtered and pumped into a strata at 1,400-ft. depth. Problems of well maintenance including means of detection of corrosion and replacement of well sections are discussed. In the second case (102), wastes which were formerly discharged into an adjoining swamp, resulting in its gross pollution, are now lime neutralized, clarified, and polished through a precoat vertical-leaf pressure filter and injected at the 1,300-ft. level. Unrecoverable waste solvents are incinerated. The swamp now receives only clean cooling water and has been restored to its original condition, and it now aids in recharging the local aquifer which furnishes the industrial water supply.

Treatment of tank car washing wastes is reviewed by Gutzeit (54). Finely divided coal is used to absorb phenols and oils from washings at pH 4.5. Coal is removed by flotation and the effluent is treated with ferrous sulfate and lime to flocculate additional sludge. Effluent is mixed with sanitary sewage and treated on a trickling filter, then sterilized with chlorine dioxide which also destroys residual phenol. Neutralization and phenol

treatment are automatically controlled. Operating costs are $15 per day for 50,000 gal. of waste containing 20 p.p.m. phenol.

A similar treatment method used at a British insecticide plant is discussed by Sharp and Lambden (129). Raw materials finding their way into the plant sewers include phenols, phosphoorganics, copper oxychloride and D.D.T. Activated carbon is used for phenol removal by adsorption. Carbon is regenerated by steaming at 600°C. Effluent is lime treated for copper removal and the wastes are then treated in combination with sanitary sewage on trickling filters followed by an aeration tank. The B.O.D. and phenol removals average 98.5 and 99 per cent, respectively, at a total cost of $3 per 1,000 gal. treated.

Weyermuller and Morris (148) discuss treatment of petro-chemical wastes using redox-potential controlled chlorination to destroy cyanides and steam stripping followed by incineration to remove other components such as acrylonitrile, vinylchloride and acetylene. Tatlock describes (135) steps taken by a dye-stuff plant to reduce sewer surcharges by installation of sedimentation, sludge concentration and sludge filtration facilities. Residual B.O.D. remained somewhat higher than local ordinance requirements but surcharges for this component were much lower than for suspended solids. Provision was made for the future installation of aeration facilities, if needed.

Removal of taste and odor producing components from cosmetic wastes (14) was accomplished by lime-alum flocculation and flotation for solids removal followed by addition of activated carbon and filtration through diatomaceous earth filters. Plant investment was $45,000 and 4,000 g.p.d. are treated at a cost of $27 per day. Lynn and Powers (85) published results of early work on identifying the various bacteria capable of decomposing phenolic wastes. Sources and relative occurrence of different groups are summarized.

Howe and Coates (61) reviewed waste disposal practice at a biologicals plant producing vaccines, antitoxins and antisera. Wastes include blood, discarded eggs, animal excreta, etc., and are treated by use of Imhoff tanks, trickling filters, sedimentation and drying of sludge on sand beds. The wastes totaled 15,000 g.p.d. and had a B.O.D. of 10,000 to 17,000 p.p.m.

Edwards and Ingram (43) studied the removal of color from TNT waste in the laboratory and the field. The results showed that TNT Sellite waste could be chlorinated directly in a column with more than 90 per cent color removal with a dosage of about 9,000 p.p.m. chlorine. Neutralization of acidity produced by chlorine did not cause the color to return.

Coal Wastes

A method for recovering coal from water-borne suspensions was patented by Chamberlain, Waters, and Robertson (31). They found that the quantity of conditioning and frothing agents used in froth flotation of coal fines can be reduced if the stream of air-agitated mixture of agents and suspension is divided into a main and a secondary flow and the froth is removed from the main but not from the secondary flow which is returned to the initial mixing point. Inichar (66) tested coal washery waste containing 14.6 per cent combustible carbon in a shaft-type gas producer. The resultant gas had a heating value of 1,068 to 1,510 kcal. per cubic meter, but the ash contained 8 per cent carbon. It would be impractical to gasify refuse with less than 15 per cent combustible carbon. On the other hand, Merteus, Hellinckx and Verhille (89) found that washery waste with 14 per cent combustible carbon could be fired efficiently on a boiler grate if it was

held in the fuel bed for two hours at 800°C. Koppers (76) found that flotation sludge from anthracite washing could be converted easily to combustible coke by combining it with 10 to 15 per cent of a carbonaceous fuel rich in gas, compressing the mixture, and carbonizing it at 800° C.

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Coke Oven Wastes

A study of the composition of ammoniacal liquor was reported by Blackburn *et al.* (21). Chromatographic methods were used to identify 40 organic compounds in the liquor. The percentages found in the organic extract were: phenol, 30; the three cresols, 20; all other monohydric phenols, 7 and all polyhydric phenols, 30. Wedgewood and Cooper (146) found that the chief organic constituents of still liquor are monohydric phenols, naphthols, dihydric phenols and their alkyl derivatives. Among the neutral compounds they identified: pyrene; fluoranthene; 1,2-benzanthracene; chysene; perylene; 1,2-benzpyrene; 3,4-benzpyrene; anthanthrene and possibly triphenylene. Solid matter in the liquor contained: pyrene; fluoranthrene; perylene; 1,2-benzpyrene; 3,4-benzpyrene and anthanthrene. Cooper (33) reported that a plant using butyl acetate for dephenolizing still liquor has been operating for two years. It recovers 95 per cent of the monohydric and 75 per cent of the polyhydric phenols; it is believed that 90 per cent removal of the latter class can be attained. Jelinek (67) called attention to the value of phenolic compounds as starting materials for organic synthesis. The per cent composition of a butyl acetate extract of liquor from low-temperature carbonization of brown coal was: pyrocatechol, 24.8; 4-methylpyrocatechol, 28.6; 3-methylpyrocatechol, 8.3; resorcinol, 4.3 and others 21.1 per cent. He discussed the following possible applications: hydrogenation to various derivatives of cyclohexane; oxidation to muconic acid as a possible starting point for nylon-type fibers; alkylation to polymerization inhibitors and stabilizers; ammonolysis of pyrocatechol to o-phenylenediamine, conversion to o-aminodiphenylamine, followed by condensation with phenanthracene quinone to Flavindulin O; possible uses of pyrocatechol condensates for plastics.

Use of phenolic effluent as a flotation agent at coal washeries is described by Barrett *et al.* (16). The phenolic content of the liquor is reduced in the process from 1,000 p.p.m. to 150 p.p.m. The waste water is treated by biological filtration which reduces the phenol to less than 10 p.p.m. Inorganic nutrient is added equivalent to 3 per cent of the phenol load. The filter was seeded with well-manured garden soil. Total operating cost is about $0.01 per ton of coal carbonized at a 1,500-ton coke works. Gutzeit (53) described a plant for treatment of the complex wastes produced at a tank-car cleaning plant. Phenol is removed by adsorption on pulverized anthracite coal followed by biological oxidation. The final effluent is treated with chlorine dioxide to insure complete destruction of phenol. Meissner (88) used a laboratory activated sludge plant to remove 85 per cent of the phenol from a waste containing 1,800 to 2,000 p.p.m. Hydrogen sulfide up to 500 p.p.m. did not interfere; it was completely oxidized to thiosulfate and sulfate. The number of protozoan species was reduced by phenol, and total counts were vari-

able. Phenol removal by a laboratory trickling filter was 75 per cent less than with activated sludge. Badger (15) points out that, although it is possible to remove by bacterial oxidation nearly all the phenolic substances in spent liquor from vertical retorts, there remains a residue with an oxygen absorption value of 300 to 400 p.p.m. which is very resistant to bacterial treatment. Finch (47) found that dephenolized gas liquor could be treated by the activated sludge process in concentrations of 1.5 per cent. The aeration period was 17 to 18 hr. as compared with 9 hr. for sewage alone.

Destruction of phenols in coke plant waste by ozone was reported by Hann and Hiegowski (55). Wastes containing up to 100 p.p.m. could be reduced to 1 p.p.m. with 500 p.p.m. of ozone. The treatment is carried out at pH 10.5 to 12.5. Williams and Hall (149) found that ozone will oxidize thiocyanate or thiosulfate in preference to phenol if the pH is 8.4 or less.

A process for fixing nitrogen compounds in still waste for use as fertilizer was reported by Cooper *et al.* (32). After removal of phenol the liquor is treated with excess nitric acid to form ammonium sulfate and nitrate. By adjusting the proportions of ammonia and nitric acid a neutral liquor of low toxicity is produced. A steel company reports (9) that it is converting coke-oven ammonia to diammonium phosphate instead of the conventional ammonium sulfate. This compound contains 74 per cent available plant nutrients as compared with 20.5 per cent for amonium sulfate and 50 per cent for triple superphosphate.

Anderson and Hansen (4) report that anion exchange resins will sorb phenol to about the same degree as activated carbon. The phenol can be stripped by eluting with methanol.

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Petroleum Processing Wastes

Identification of hydrocarbons from refinery waste in surface water is a matter of some difficulty. Oxidation of hydrocarbons and the presence of other pollutants obscure hydrocarbon properties used as a basis for identification, particularly infrared spectra. Rosen and Middleton (115) concentrated the organic matter in three samples of surface water on activated carbon. Adsorption chromatography on silica gel was used to remove oxygenated substances from the carbon extracts. In addition, the hydrocarbons could be separated into aromatic and aliphatic fractions. Infrared spectra

of corresponding hydrocarbon fractions of five refinery wastes showed a remarkable degree of similarity. The method provides chemical evidence, independent of odor evaluations, of the presence of low concentrations of refinery waste in surface water. Johannesson (69) points out that the usual methods of oil identification are of little use in identifying the source of fuel oil which has emulsified or which floats as a thin film on coastal waters. He uses a method which depends upon the nickel and vanadium content of the oils. These metals are held as coordinated complexes with prophyrins and are not affected by sea water. The concentration of these metals in the ocean is insignificantly small as compared with the amount in oils.

Dissolved-air flotation for removal of suspended matter and oil from refinery wastes is being used at a number of plants. Osterman (99)(100) has discussed the basic principles of the treatment and operation at a large plant.

De Laporte (36) provides recent data on operation of the activated sludge waste treatment plant at Sarnia (see 1954 Review). The first five months of operation showed 100 to 150 lb. per day of phenol of which 95 per cent was destroyed, and all sulfide was removed despite mechanical difficulties and adverse weather conditions. Experience indicates that the process will operate with dissolved and emulsified oil contents up to 220 p.p.m., phenol 200 p.p.m., and sulfide 250 p.p.m.

Laboratory studies of the treatment of emulsified oil are reported by Brannan, Etzel and Bloodgood (26). It was conceived that oil trapped in a ferric hydrate floc could be released and recovered by dissolving the floc. The emulsion containing ferric sulfate was flocculated with lime, allowed to settle, and withdrawn. The pH of the slurry was reduced to 2.5 with sulfuric acid and allowed to stand. The liberated oil rose to the surface and the acidified ferric sulfate was added to another batch of emulsion. The new batch was flocculated with lime and the cycle repeated. The process removed 96 per cent of the oil. Schulze (124) found that 25 kg. of powdered sodium nitrate reduced hydrogen sulfide from 12.8 p.p.m. to 9.3 p.p.m. when spread on the surface of a 4,000 cu. m. duck pond 1.5 m. deep. On a later date 30 kg. reduced hydrogen sulfide from 3 p.p.m. to 0.0 p.p.m. and 27 p.p.m. the B.O.D. from 27 p.p.m. to 19 p.p.m. The species and physiology of nitrate-reducing bacteria are discussed.

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Pickling and Acid Wastes

A process for treating spent pickle liquor with raw coke oven gas was patented by Hoak (59). Coke oven gas from the detarrer is scrubbed with pickle liquor forming a slurry of ferrous sulfide and ferrocyanide in a solution of ammonium sulfate. Oxidation of the slurry with air or oxygen at about 75° C. and at a pH below 8 converts the ferrous sulfide to ferric oxide and elemental sulfur while the ferrocyanide remains insoluble. The sulfur is recovered by froth flotation, the oxide is filtered off, and the ammonium sulfate is recovered as a pure salt in an evaporator-crystallizer. Ferrocyanide is leached from the iron oxide with lime slurry as a by-product. The oxide is sintered for recharging to blast furnaces. The process, which produces no waste water, is being tried in a pilot plant by a steel company. A somewhat similar process was described by Dixon (37). The slurry from a six-stage scrubber is treated with acid to release hydrogen sulfide which is converted to fresh acid or sulfur.

Permselective electrolysis of pickle liquor was studied by Bramer and Coull (25). Spent liquor flows through a series of cell compartments formed by alternating anion and cation permeable membranes. When electric current flows through the cell free acid is recovered from cathode compartments while iron is deposited on the anodes.

Francis and Lynch (50) patented a continuous process for separating ferrous sulfate from pickle liquor and returning the recovered acid to the picklers. The British Iron and Steel Research Association (8) piloted a process for roasting ferrous sulfate and oxidizing the evolved sulfur dioxide to sulfuric acid by the autoxidation process. The process yields 40 per cent acid. Fackert (45) described a closed-circuit pickling-recovery process wherein ferrous sulfate is converted to sulfuric acid and iron oxide by treatment with nitric acid. The resultant nitrous acid is oxidized to nitric for re-use. Pickling with bisulfate has again been proposed by two authors. Miller (90) neutralizes the ferrous ammonium sulfate in the spent liquor with ammonia, oxidizes the precipitated ferrous oxide with air, filters, and crystallizes ammonium sulfate by evaporation. This salt is converted with heat to the bisulfate for re-use.

Recovery of free acid by ion exchange was evaluated by Fradkin and Tooper (49). Reents and Kahler (111) describe a process for removing iron chloride from strong hydrochloric acid by ion exchange. An ion-exchange technique for analyzing pickle liquor was developed by Fisher and Kunin (48).

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Plating and Cyanide Wastes

The possibility that ground water might be contaminated by percolation from lagooned cyanide solutions sometimes causes concern. Renn (114) studied the capacity of various soils to destroy cyanide. A battery of columns was filled with humus-rich topsoils saturated with a solution of 100 p.p.m. cyanide as KCN. The tubes were sealed and fed 90 ml. per day of the 100 p.p.m. solution. There was an immediate reduction of cyanide to 53 p.p.m.; after 20 days the effluent reached an equilibrium value of 0.4 p.p.m. After 30 days soil from the tops of columns contained 2 to 5 p.p.m. cyanide, from bottoms 0 to 1 p.p.m. Bacterial fermentation was ruled out as a mechanism because the rate of breakdown was about the same for sterile and non-sterile soils. The same paper reported that, under constant-flow, constant-concentration conditions, 100 per cent survival of white crappie for 10 hr. is uncertain when concentrations exceed 0.03 p.p.m. N as cyanide and no test specimens survived 10 hr. at concentrations greater than 0.06 p.p.m. Lactonitrile tolerance was 0.09 p.p.m. N, acrylonitrile somewhere between 10 and 18 p.p.m. N.

Heukelekian and Gellman (57) studied the effect of Cu, Ni, Zn, Cd, Cr^3, Cr^6 and Co on the oxidation of sewage and activated sludge-sewage mixtures. The paper contains 24 tables of data. Summary findings are:

1. The order of 5-day oxygen demand was Ni, Cu, Co, Cd, Cr^3, Zn and Cr^6.

2. For each ion the concentration required for a particular degree of retardation of oxidation of sewage substrate increased with the time interval.

3. Toxicity of metal ions, as indicated by oxygen consumption, is not a fixed value but increased tolerance develops by adapting the seed to repeated additions of the ions.

4. Toxic effects were less for activated sludge than for comparable concentrations added only to sewage.

5. The order of decreasing toxicity for activated sludge-sewage mixtures was Ni, Cu, Cr^3, Cd, Zn, Co and Cr^6.

6. In contrast to sewage, in activated sludge-sewage mixture the retarding influence occurs after prolonged periods of oxidation rather than during the initial period.

7. Addition of peptone to sewage did not decrease the toxicity of Co.

8. For a given toxic ion concentration, there is an increased retardation of oxygen utilization with decreased sewage strength.

9. Where both sewage and metal concentrations are decreased in the same proportion the same toxic effect is observed.

10. Initial pH values of sewage markedly affect the toxicity of particular concentrations of Cu and Cr^3, and this toxicity decreases with increasing pH.

In a study of cyanide destruction on a trickling filter, Pettet and Ware (103) found a wide variety of Gram-negative and Gram-positive bacilli, some algae and protozoa. When cultured on nutrient agar none was capa-

ble of destroying cyanide. Finally a large Gram-positive filamentous organism was isolated from a small piece of coke from the filter. Provisionally classed as an Actinomycete, it grows on silica gel as hard, powdery pure white colonies consisting of Gram-positive hyphae, 1–2 microns in diameter. It converts cyanide almost quantitatively to ammonia. Optimum growth temperature is 30° C. but it will withstand 55° C. for 15 min. Growth is enhanced by traces of Fe, Mg and Cu. Good growth occurs only between pH 7.5 and 9.0. It does not grow on glucose-ammonium salts or peptone media. Concentrations of cyanide up to 150 p.p.m. were destroyed readily.

A full description of waste disposal methods for electroplaters discharging about 10,000 gal. per day is provided by Dodge and Zabban (38). Based on regulations of a number of states, they recommend that concentrations of the wastes discharged to the sewer should not exceed the following: cyanide, 0.1 p.p.m.; ferro- or ferricyanide, 0.4 p.p.m.; copper, 0.2 p.p.m.; zinc, 0.3 p.p.m.; cadmium, 0.3 p.p.m. They know of no regulations on discharge of cyanates, but limitations on discharge of ammonium compounds would apply to cyanates. Details are given for hypochlorite treatment, including flowsheets and analytical methods.

Recovery of metals by ion exchange is being used increasingly. Tooper (138) describes a new resin with a long life under oxidizing conditions. It is expected that solutions of 250 g. of CrO_3 per liter can be handled without dilution. Helbig (56) recommends using activated carbon ahead of ion exchangers to remove organic matter to protect exchange capacity. He suggests that 10 p.p.m. of carbon will generally be required for each part per million of organic matter removed. Keating, Dvorin, and Calise (72) discuss various aspects of ion exchange. They point out that cation units should precede anion exchangers wherever possible to protect the latter from suspended matter and metal ions. Where this is not feasible a filter should be provided. Septum filters have been effective in removing plating-bath additives. Studies are in progress to develop a method for treating metallic cyanides by ion exchange.

Neutralization and filtration of plating wastes are discussed by Ledford (81), who found that the type of alkaline agent materially affects the characteristics of the precipitated sludge. Studies of a synthetic waste showed that aging improved filterability under certain conditions. A small amount of ferric iron reduced filtration rates for unconditioned sludge. Lukas (84) states that two limestone beds in series have proved effective for holding waste water in the pH range 4.5 to 5.2. The treatment costs $0.17 per 1,000 gal. Griffith (52) describes a system of lagoons which handles soaps, acid and alkaline cleaners, oils, solvents, plating wastes, paint, boiler components, etc. Final effluent shows that oil is reduced 99.5 per cent, suspended solids 99.2 per cent, and B.O.D. 97.9 per cent.

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Tannery Wastes

Mathis (86) determined the effectiveness of screening, settling, and centrifuging for treating waste waters resulting from softening, depilation and fleshing of skins. Centrifuging was most effective but not practical on a large scale. Various methods of further treatment by chemical means were also investigated. These methods included chlorination, coagulation with ferric sulfate, and removal of sulfides by acidification with sulfuric acid. Schlichting (118) describes tests in which tannery effluents after settling were mixed with activated sewage sludge. Toxicity tests were made by the addition of reacted liquor to aquarium fish. It was found that when 1.5 gal. of effluent were mixed with 150,000 gal. of sludge, the product was non-toxic after 14 days.

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Textile Wastes

The Piedmont Section of the American Association of Textile Chemists and Colorists (AATCC) National Committee on Stream Pollution has classified and abstracted (3) more than 230 references on textile wastes and waste treatment.

Souther and Alspaugh (131) reported on pilot-plant studies being made on the treatment of mixtures of domestic sewage and textile mill wastes by high-rate trickling filters, by activated sludge and by chemical treatment. Their results indicate that pretreatment by trickling filter and subsequent treatment by activated sludge is the most efficient method that can satisfactorily be used for treatment of highly alkaline textile wastes. The Sanitary Engineering Research Committee of the American Society of Civil Engineers presented data (116) of Souther and Alspaugh which showed that a highly alkaline textile waste-sewage mixture had been successfully treated without neutralization on a high-rate trickling filter. Sawyer *et al.* (117) conducted laboratory experiments in which the B.O.D. of cotton kier wastes was successfully reduced by activated sludge at pH values as high as 10.5. Oldaker (97) studied the effect of nutritional deficiency, pH

and aeration on the biological stabilization of flax-cooking liquor. It was found that maximum B.O.D. removals were attained when the pH was adjusted from about 11.5 or 12.0 to 7.5, and 1 p.p.m. of phosphorous was added for each 98 p.p.m. of B.O.D. Husmann (63) reported that experiments indicated purification of textile waste waters can be accomplished in trickling filters without the addition of sewage, if effluent is recirculated at a ratio of (3:1) three parts sewage to one part raw waste.

Snyder (130) discussed the substitution of synthetic film-forming compounds for natural sizing materials to reduce the B.O.D. of wastes from a dyeing and finishing plant. The AATCC Committee on Stream Pollution reported (132) on the 5-day B.O.D. of about 154 textile chemicals. Lingelback (83) measured the B.O.D. of dye liquors containing respectively, sulfur, indanthrene and substantive dyes.

Kehren and Thewis (74) (75) studied the adsorptive capacity of ferric hydroxide gels using indigo carmine and benzopurpurine. Their results are discussed with reference to treatment of wastes from dye works. Kehren and Denks (73) concluded that dye liquors could be economically coagulated with ferric chloride only in the acid range of pH values.

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Wool Scouring Wastes

The United States Public Health Service (143) has published a 14-page summary of the methods employed in the treatment of wastes from the wool

processing industry. A bibliography on woolen wastes is included. McCarthy (87) reported results of experiments in which wool scouring wastes were satisfactorily treated on high-rate trickling filters. Taylor suggested (136) that suint salts and waxes be extracted from wool wastes with organic solvents. The suint salts can be precipitated with calcium chloride and removed by centrifuging. The waxes can be recovered by fractional cooling of the solvent.

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Pulp and Paper Wastes

Kraft or Sulfate Process Effluents

Plant-scale treatment of kraft mill effluents using a modified activated sludge process continues as the most advanced development in this phase of effluent treatment. Most of the interest is centered in the treatment plant of the West Virginia Pulp and Paper Co. at Covington, Va. Miller and Knisker (91) describe the background and development leading to the design of the treatment facilities while two other articles (7)(41) describe the actual installation and operation of the plant designed for the treatment, ultimately, of 24 m.g.d. with 85 per cent reduction in B.O.D. Biological oxidation of kraft effluents through natural means is discussed by Webster (145) who describes the effluent stabilization system used by a large mill in the South where strong and weak effluents are lagooned separately and then mixed through two oxidation ponds and through a series of natural ponds. The entire system is 7½ miles long and the stabilized effluent has a B.O.D. of 30 p.p.m. when it reaches the point of discharge into the river. Wetherhorn (147) describes equipment and operational changes in an unbleached kraft mill which produced a 19 per cent increase in production and a 58 per cent reduction in pollutional load. In color removal from kraft effluents, Moggio (92) proposes the use of hydrated lime to precipitate the color bodies and treatment of the resultant hydrous sludges by carbonation followed by the further treatment of the carbonated sludge with spent kraft cooking liquor (black liquor). After the treatment the liquor would be returned to the kraft process chemical recovery system and the dewatered and washed sludge could be burned in the lime kiln to recover the lime for re-use in the treatment process. Another publication (94), dealing with the same subject, describes the work leading up to the development of the process described by Moggio (92) as well as the treatment, by carbonation only, of the sludges produced by lime treatment of kraft mill effluents. Berger (20), in a statistical study of oxygen consumed ($KMnO_4$ method) and B.O.D. data, finds a correlation between the two tests for untreated kraft effluents, but concludes that oxygen consumed tests should not be used to determine treat-

ment efficiency of a biological treatment process for kraft effluents.

Sulfite Process Effluents

It appears that the major effort on the treatment of sulfite pulping effluents is being directed toward by-product recovery and utilization, if one is to judge by the number of publications and patents dealing with this approach. Processes for the recovery and re-use of the chemicals used in the pulping process, however, have not been neglected. Amberg and Strang (2) describe an underwater diffusion line for spent sulfite liquor which is effective in reducing shoreline pollution and excessive slime growth. Impermeabilization of a sulfite liquor storage lagoon by the use of a chemically treated soil blanket, costing 10 per cent more than untreated soil, is described by Lambe and Anderson (80). In soil filtration studies Buehler (28) found that B.O.D. reductions resulted from the removal of sugar, sulfur and suspended matter from spent sulfite liquor. B.O.D. reductions decreased with time or with an increase in the strength of the feed liquor while the liquor pH was raised to neutral. Craig *et al.* (34) describe the full-scale installation of a thermal-compression evaporator for spent sulfite liquor consisting of a stainless steel, long tube, vertical evaporator body used in conjunction with a steam driven turbo-compressor. The unit is designed for 30,000 lb. of water evaporation per hour with a ratio of 16.7 lb. of water evaporated per pound of steam. Scaling is controlled by daily cleaning with recovered distillate. Scholander (119) studied the sulfur balance in the evaporation of spent sulfite liquor and found that up to 20 per cent of the sulfur is lost in condensates, steam and vent gases. Losses increased with increasing temperature and decreasing liquor pH.

In the utilization of spent sulfite liquors for agricultural purposes, Faldner (46) found that treated and diluted spent liquor hastens the germination of wheat in unproductive soil. Bollen (22) reports that dehydrated ammonia base spent liquor has direct fertilizer values which are enhanced by the slow and prolonged availability of the nutrients. Lignin contributes to the formation of humus. Anger (5) reports on experimental work showing that capillary migration of water in the soil is completely prevented by small quantities of spent sulfite liquor and sodium dichromate.

Semi-Chemical Process Effluents

Plant scale installations of the Zimmerman recovery process for organic effluents are described (12), one application being for spent semi-chemical liquors. The process uses air at 1500 p.s.i.g. and temperatures exceeding 525° F. to bring about oxidation of organic and inorganic compounds. The steam and noncondensable gases formed drive turbines for air compression. Inorganic compounds are recovered for re-use. Berger (19) reviews the research on chemical recovery and biological oxidation processes for spent neutral sulfite semi-chemical liquor. O'Donoghue (96) describes the various processes developed for the evaporation, burning and recovery, and treatment of spent semi-chemical liquors, including the Mead, Sivola, Sulfox Institute of Paper Chemistry, Zimmerman, Bickell and Tretheway, Rayonier and the Hydrotropic pulping processes. Edwards (44) concludes that the economic recovery of chemicals and heat are more difficult to achieve in the semi-chemical process than in the acid sulfite and kraft processes. Owen and Moggio (101) present data obtained in the evaporation of spent neutral sulfite semi-chemical cooking liquor using submerged combustion. In a cost comparison with multiple effect evaporation, the submerged combustion method showed higher costs although its ap-

plication in certain instances might be justified. Analyses of the evaporated liquor indicated the feasibility of by-product acetic acid recovery.

In the realm of treatment and disposal methods Reaves *et al.* (110) describe the operation of a modified activated sludge plant for the treatment of 1 m.g.d. of a white water-spent neutral sulfite semi-chemical liquor mixture. Ammonia is used as a bacterial nutrient. The plant treats an effluent with 350 p.p.m. B.O.D., achieving an 87 per cent reduction. Maximum loading was 39.5 lb. of B.O.D. per 1,000 cu. ft. of aerator capacity. Spent semi-chemical liquor can be lagooned in hot weather without odor production if the solids concentration exceeds 15 per cent (95). Odor-masking compounds were not too effective in masking odors, but high concentrations of sodium hypochlorite and lime were effective.

White Water Effluents

Economic factors entering into the selection and use of three basic types of white water treatment units, namely, reclaimers, reactivators and flotation units are discussed by Calise and Keating (29). Gehm (51) describes an installation where white water is treated to remove fiber and inorganic pigments. Lime is added to raise the pH and coagulate the suspended matter. The clarified effluent is re-used while the sludge is recovered for use in lower grade products.

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WATER POLLUTION

Biology

Water Supplies

One of the outstanding problems created by the addition of wastes to our water courses is their effect on our water supplies. These effects may be either direct or indirect. Direct effects result from addition of materials which produce taste and odor, increase the dissolved solids, acidity, alkalinity or turbidity. Indirect effects include such matters as the promotion of the growth of interference organisms through fertilization. Organisms in water supplies can lead to a variety of problems among which are tastes and odors, clogging of filters, growth in pipes, cooling towers and reservoirs, production of floating mats, infestations in purified water, changes in water quality (pH, hardness, turbidity, etc.), and the production of toxicity. Some of the problems produced by organisms in water supplies are described and summarized by Palmer and Tarzwell (144) who also list species characteristics of polluted and

clean water and present six colored plates of algae which illustrate 132 species important in water supplies. Some of the beneficial effects of algae and algal control are also discussed.

Tastes and Odors

It is reported by Swartz (189) that microscopic organisms are the most common cause of objectionable taste and odor in surface waters or in ground water stored in open reservoirs. It was found that many of the organisms have seasonal peaks in abundance. Optimum temperatures for diatoms were in the range of 40° to 60° F. Odors produced ranged from aromatic to fishy and were noted when population levels were at 2,000 standard units per milliliter or greater. Optimum temperatures for blue-green algae ranged from 60° to 80° F. At low concentrations these algae are reported to cause a grassy or moldy odor, while at higher concentrations a pigpen odor was evident. The green algae, which had optimum temperatures of 50° to 70° F., produced a grassy or nasturtium odor at high concentration. The yellow-green algae are cold water forms (40° to 50° F.) which are most abundant in early spring. They produce odors which are noticeable even at low concentrations of organisms. The dinoflagellates are likely to occur at any time.

Water supply problems have arisen due to the pollution of the Elbe River by untreated sewage and industrial wastes (68). Experiments indicated that tastes and odors caused by the decomposition products of algae were not sufficiently reduced by chlorine dioxide, while experiments with filtration through absorptive material were successful. Hettche (95), however, reported that chlorine dioxide at 0.8 p.p.m. removed odor from Elbe River water.

Laboratory studies showed that the odors produced by two species of *Oscillatoria* were associated with changes in metabolism (205). When starved or when the nutritive medium was abruptly changed, *O. splendida* produced earthy odors. It was stated, however, that simultaneously the medium became turbid with slime produced on autolysis and that the odor was noted when the cells were damaged by maceration, desiccation or super-cooling. Under alkaline conditions with increase in temperature and when undernourished, *O. aghardii* produced a rotten fruit odor. Growth of both species was stimulated by organic matter, phosphorus and nitrogen. These findings were confirmed by two other Russian workers, Baslavskaya and Kislyakova (25), who reported that when nitrogen and phosphorus are introduced simultaneously, there is an increase of photosynthetic activity.

Ohle (139), in lake eutrophication studies, reported that a sewage treatment plant effluent discharged into a lake caused such vigorous algal growth that the effects of secondary pollution were similar to those of pollution by untreated sewage. Investigations were made on effects of different substances on algal growth. It was found that the addition of ammonium and phosphate ions caused vigorous growth of unicellular green algae and that algal development and content of chlorophyll were highest in the presence of both phosphate and nitrate. The author believes that the nitrogen demand of both oligotrophic and eutrophic waters can be satisfied under natural conditions but, since the natural supply of phosphate is small, the optimum amount for vigorous algal growth is only reached by the addition of human wastes. Further, the addition of phosphate is regarded as the initial and main factor in the development of eutrophic conditions.

Filter Clogging and Growth

Hofmann (99) describes the difficulties that were encountered at the St.

Gallen (Swiss) water works which treats Lake Constance water by rapid filtration followed by slow sand filtration. A comparison is made between the pore size in filters containing sand of different sizes and the size of the organisms present in the lake water. Diatoms, such as *Tabellaria* and *Fragilaria*, were retained to a large extent in the rapid sand filter but types more spherical in shape, such as *Cyclotella*, passed through. The rapid sand filter reduced the plankton count 88.3 per cent in 1952 and 92.7 per cent in 1953. Studies indicated that in October and November, 1953 the rapid sand filter removed 95 per cent of the filterable material from the raw water. It was found that the coarser sand (1.2 mm.) was more efficient and effective.

Bottom-living algae were collected from eight slow sand filters of the Newcastle and Gateshead Water Company at Whittle Dene, Eng. (41). Throughout most of the year diatoms dominated the flora and there were spring and autumn maxima and a midsummer minimum of numbers. Marked differences were found in the composition of the flora of recently cleaned beds and those which had been in use for some time. Species present in the recently cleaned beds were found rarely or not at all on "older" beds. The protozoan population increased with time and its increase coincided with the decline of bottom-living diatoms.

Growths and Deposits in Pipes

The deposits in water mains from Warche and Gilippe Dams (Belgium) consisted mostly of Mn_3O_4 or MnO_2 and were due primarily to biological action (206). Of the dried deposit, Mn_3O_4 represented 55.57 per cent; Fe_2O_3, 3.43 per cent and SiO_2, 6.04 per cent. Cellulose comprised 1.61 per cent of the wet deposit. After 16 years, the deposit was approximately 16 mm. thick. It was calculated that with 70,000,000 cu. m. of water passing annually through the conduit, 0.35 cu. mm. of deposit was formed by each liter of water. Although the water contained 10 times more iron than manganese in certain cases, the latter was selectively precipitated. The author believes that *Leptothrix* bacteria oxidize manganese salts to Mn_3O_4.

Control of Nuisance Organisms

At Norwich, Eng., *Nais* worms together with smaller numbers of nematodes, diatoms, flatworms, rotifers, *Cyclops* and *Daphnia* were found in the distribution system after the water had passed through a slow sand filter (110). Treatment with high concentrations of chlorine and $CuSO_4$ failed to give more than temporary relief. The microstrainer with apertures of 23 μ is being installed between the slow sand filter and the post chlorination tank, since results with an experimental microstrainer indicated that it was successful in removing the organisms from the water.

In September, 1953, many bristle worms, *Nais*, of about 1 cm. in length were found in the covered swimming pool at Oldenburg, Germany (7). One liter of sodium hypochlorite to 90 cu. m. of water killed the worms in the pool but not in the filter. Even much greater concentrations (7 l. to 9 cu. m.) were unsuccessful. When 7 l. of Lysolin were mixed with 30 cu. m. of water and continually circulated through the filter, positive results were obtained. It appeared, later, that in water with very low turbidity the worms died and disintegrated without the addition of chlorine.

Dias (61) reports that a culture of *Bacillus pinottii* and peptone was successful in the control of certain mollusks. Certain non-sporulating bacteria, cultivated in sugar, caused perforations in the shells and death of many mollusks. Foci of *Planorbidae* may be extinguished by application of *Saccharomyces cerevisiae* and sugar or molasses in a relatively high concen-

tration. A rapid extinction of two foci of *Australorbis nigricana* was obtained by two treatments with distillery syrup. Such methods are, of course, not practical in most water supply systems.

Bringmann (38) reports that ozone destroys resistant spores of soil bacteria in 14 min. at a final concentration of 0.35 mg. per liter. Experiments also showed that ozone was lethal to unicellular algae, *Ankistrodesmus,* other phytoplankton, *Volvox* and *Euglena,* zooplankton, *Daphnia* and *Cyclops,* and to larger animals such as fly larvae, tubifex worms and water mites.

In experiments (103) on the toxicity of quaternary ammonium compounds to algae and fish, it was found that such compounds were lethal to fish at concentrations of 1 to 4 mg. per liter at 20° C. depending on the length of the alkyl chain. It was concluded, however, that quaternary ammonium compounds in concentrations of 1.2 to 2.0 mg. per liter can be used to control algae without permanent injury to fish.

Palmer and Maloney (143) reported on the screening procedures used in testing candidate algicides. The screening procedure involved the addition of 2 p.p.m. of the gross material under test to the culture medium previous to its inoculation with a particular alga. Results for 76 substances were tabulated. Inorganic and organic salts, rosin amine compounds and antibiotics tended as groups to show high toxicity. In general, the more sensitive algae were *Microcystis, Nitzschia* and *Gomphonema,* while the resistant genera were *Scenedesmus, Chlorella* and *Cylindrospermum.*

Delrad 70 (Rosin amine D acetate, 70 per cent solution in water), at concentrations of 0.25 to 0.50 p.p.m. of active ingredient, killed *Ulothrix* in 5 to 6 hr. with no apparent deleterious effects on brook trout fingerlings. The hatchery water had a temperature of 48° to 50° F. and a total alkalinity of 127 p.p.m. Although *Ulothrix* declined, diatoms increased (106).

Since its introduction in 1937, sodium pentachlorophenate has been successfully used for the control of slime and algae in cooling water systems when used at concentrations of 15 to 20 p.p.m. (216).

Copper sulfate gave incomplete control of plankton algae in the Philadelphia reservoirs, particularly when growth was stimulated by the addition of sodium hexametaphosphate, which was used to increase the pH and reduce the corrosiveness of the water. Chlorine dioxide gave almost complete control of the algae under this condition (167).

Toxic Algae

Rose (170) reported a heavy mortality of wildlife and livestock at Storm Lake, Iowa in the fall of 1953. Death of the animals was attributed to their drinking water containing toxic blue-green algae, *Anabaena flos-aquae.* To prevent a recurrence of the trouble, the lake was sprayed with $CuSO_4$ in the fall of 1953. Practically no *Anabaena* developed and there was good control of *Aphanizomenon* and *Microcystis* which at times developed in great quantities. Care must be used in the application of $CuSO_4$ as experimental data show that quantities as low as 0.5 p.p.m. are lethal to the newly hatched *Stizostideon v. vitreun* and to some fish food organisms, particularly *Daphnia.*

Fish kills associated with the red tides off the west coast of Florida are attributed to the high incidence of the marine dinoflagellate, *Gymnodinium brevis.* Wilson and Collier (217) report the development of methods for culturing the organism. Investigations seem to indicate that heavy rainfall and subsequent increased river discharge are instrumental in initiating blooms of *G. brevis.* Sea water con-

taining 4 to 10 ml. of river water per 100 ml. supported limited growths, while 7 to 10 ml. of river water or peat extract per 100 ml. of sea water produced better growths. Laboratory cultures of *G. brevis* have attained concentrations of more than 2,000,000 cells per liter and were toxic to *Mollienesia* and *Mambras*. Additional studies (204) have further confirmed the theory that river effluents containing organic nutrients, when combined with the correct temperature and wind conditions, produce a suitable environment for rapid reproduction of *Gymnodinium brevis*. Recently it was discovered in the Fish and Wildlife Service laboratory at Galveston that metallic copper in extremely small quantities is highly toxic to *G. brevis* (14). After further experimental work in the laboratory, metallic copper in the form of large screens and possibly copper ore tailing will be tried on a field-scale test to determine its control effectiveness as a substitute for the more expensive $CuSO_4$ In the meantime. control experiments using $CuSO_4$ will be continued.

Copenhagen (55) describes surveys made to determine the cause of fish kills off Walvis Bay, South West Africa, which usually occur annually and sometimes four to five times in a season. It was found that there is a definite relation between the fish kills and certain meteorological and oceanographic conditions which give rise to depletion of dissolved oxygen and development of sulfate-reducing bacteria with consequent production of H_2S. Blooms of toxic phytoplankton may also occur.

Surveys

Studies of the biological effects of pollution on the receiving water have been stressed in recent years. Attention is being directed toward water quality criteria for the protection of aquatic life and the effects of various concentrations of materials on different forms of life. Halsband (88) reported on investigations in Westphalia to determine the maximum permissible concentrations of impurities in streams which will allow the maintenance of normal aquatic life. To determine the degree of toxicity of a substance the oxygen consumption and breathing frequencies of the animals were measured and the threshold of disturbances determined. The Report of the British Water Pollution Research Board for 1954 (13) contains much valuable information on conditions in the Thames estuary since 1920 and the effects of pollution on fish in the River Colne. Special studies were made of the toxicity of undissociated ammonia at concentrations of 0.9 to 2 p.p.m. and higher and the effects of CO_2.

The Rhine River is a major source of water supply for some parts of Holland (114), and has a B.O.D. higher than is usually permitted in potable waters. Furthermore, the average chloride concentrations have changed from 37 p.p.m. in 1898 to 204 p.p.m. in 1953. Fishermen complain about decreased fish catches. In cold weather, self-purification cannot cope with the pollutional load. The situation has become steadily worse since World War I and international cooperation will be needed to clean up the stream.

Tamura *et al* report (190) that in Japan sulfate paper mill waste may be detrimental to fish life in the following ways: (a) by depleting the dissolved oxygen and suffocating fish; (b) by direct poisoning or killing of fish by toxic substances; and (c) by tainting the fish flesh so that it cannot be used for food.

Studies were made to correlate the invertebrate bottom fauna of San Francisco Bay with a variety of factors (74). The effects of pollution were the only ones which were obvious. In portions of the estuary where industrial wastes are released the depressing effect on the fauna was apparent.

Domestic wastes also depressed the fauna but not as much as the industrial wastes.

Algal studies in the River Colne, by means of the immersed glass slide technique, indicated that the material collected on the slides and the natural flora are at least qualitatively similar (12). It was found that there was a seasonal succession of forms. *Chironomus riparius* was found in the alpha meso-saprobic zone below sewage outfalls. Their development and subsequent emergence as adults represents a considerable loss of organic matter from the river. Distribution of animals in the bottom deposits were studied by means of core samples and by submerged traps. In favorable stretches of the river there were 20,000 *Chironomus riparius* per square meter in 1955. Much higher densities, up to 300,000 per square meter, were found in the spring of 1954. *Asellus* reached a density of 60,000 per square meter in February, 1955 and exceeded 200,000 per square meter in the spring of 1954.

Natural Purification

Natural purification consists largely of the utilization of organic wastes by living organisms. Such wastes are food for organisms and have a fertilizing effect which increases productivity and may lead to extensive and troublesome growths. Recently development of *Sphaerotilus* has caused trouble in the Columbia River. Such troubles are quite widespread as indicated by Popp and Bahr (155) who describe the mass development of *Sphaerotilus natans* in the River Oker during the sugar campaign of 1952. Quantitative measurements were made by determining dry weight, which was taken to be 8 per cent of the wet weight. Development during this season was of such an extent that it disturbed biological conditions of the stream. It was concluded that the *Sphaerotilus* developed from its "scarcity" form, *Cladothrix*, which is always present. *Sphaerotilus* flocs did not decrease in amount for some distance down stream below the beet sugar factories, showing that there was still vigorous growth on the stream bed. The *Sphaerotilus* floc settled out to form a sludge, the effects of which continued into the next summer so that the process of self-purification was retarded and only reached its full effect in late summer shortly before the start of the next sugar processing season.

Liebmann (123) concluded that the presence of amino acids in dilute solution is essential for the development of *Sphaerotilus natans*. Drifting masses developed best at low water temperatures and at a rate of flow not less than 20 cm. per second. Nutrient conditions are best below the discharge of sewage treatment plants, waste water from cellulose manufacture, sugar factories and milk processing plants. In small shallow streams masses develop most freely on the bed and banks, but in large streams masses may also develop in the open water. Examinations of growths in the Danube River below a pulp mill showed that conclusions as to the age of flocs could be drawn from the living organisms present. Flocs were found in the open water 100 m. below the mill and large flocs were present at 500 m., while growths on the bank were still small. At 100 m., the flocs were composed of sprouting filaments with white growing points and contained only a few bacteria; at 200 m. the number of bacteria had increased; at 300 m. the flocs were about 3 cm. in size, had a brownish center and contained numerous bacteria, a few flagellates and ciliates; at 1 km. they contained a community regarded as typical. The typical community remained present for a distance of 1 to 10 km. corresponding to a time of flow of 20 min. to 3.5 hr. From 10 km. to about 33 km. downstream, the growths became darker and looser in formation

and the organisms changed. In large, deep streams about two-thirds of the living fungus is carried by the water near the stream bed.

The conclusions of various investigators in regard to the relation between *Sphaerotilus natans* and *Cladothrix dichotoma* were described by Bahr (20). Observations on the Oker and its tributaries could only be explained by the assumption that *Cladothrix,* which occurred less frequently than *Sphaerotilus* but was present at all seasons, is the form of *Sphaerotilus* which occurs during unfavorable environmental conditions. Mass development of *Sphaerotilus* followed the sudden addition of large quantities of nutrient material from sugar factories. Culture experiments with both forms gave the first pure cultures of *Cladothrix dichotoma* on solid media. In liquid media with added asparagin, the *Cladothrix* form could be converted to the *Sphaerotilus* form if the nutrient solution was frequently renewed. By reinoculation on the solid medium, the *Sphaerotilus* form returned to the *Cladothrix* form. Bahr discusses this same subject in another paper (19). It is pointed out that, in lakes or stagnant water, eutrophic conditions are produced by a gradual accumulation of nutrient materials. In streams, however, the optimum concentration of nutrient matter is reached by dilution of concentrated organic or inorganic matter. Such conditions are common in rivers polluted by sewage and lead to mass development of bacterial growth, the most vigorous of which is *Sphaerotilus natans.* Dense growths of the organisms lead to the production of a sludge in which other organisms develop, especially sulfur bacteria.

The enrichment of streams by sewage plant effluents is well illustrated by the appearance of perch and pike in Lake Windermere (15). During the past 40 years there has been a progressive increase in the plankton population with the increase in the amount of sewage works effluents and the amount of calcium salts washed in from surrounding agricultural land.

Organic Enrichment

Ohle (138) describes the changing conditions in a number of lakes in Holstein due to growth of population and agricultural development. Phosphate is considered the most important nutrient material but sulfates are also considered. The rapid aging or eutrophication is described by the same author in another paper (140). It was observed that lakes in Holstein and Lake Ploner had been aging rapidly during the recent years. This accelerated aging is ascribed to increases in nutrient matter contributed by sewage, industrial waste waters and drainage from manured fields, the most important constituent being phosphate.

Biological Indicators of Pollution

A physical, chemical and biological study of 55 sampling stations was made three times during 1954 in the Long Beach-Los Angeles Harbor area (160). On the basis of dissolved oxygen, there appeared to be only two pollutional divisions, clean and polluted. However, based on the abundance of selective species of *Polychaeta,* five categories of bottom were recognized: healthy; semi-healthy I; semi-healthy II; polluted; and heavily polluted. Macro-invertebrates were completely lacking in the latter areas which were characterized by the presence of sludge beds. There was a progressive decrease in the number of *Polychaete* species from the healthy to the very polluted as follows: 7-5-5-3-0. Pollution-selective species decreased with decreasing pollution.

Stammer (183) investigated the effects on indicator organisms of different classes of H_2S and ammonia. These studies were designed to discover: (a) whether there was any connection between the resistance of or-

ganisms to these substances and their position in the saprobic system; (b) whether the threshold of toxicity of ammonia was low enough for this to be regarded as a factor in the distribution of organisms apart from the different oxygen requirements; (c) and whether indicators of polluted water had greater resistance to H_2S in the absence of oxygen than had unpolluted water forms. Fourteen indicator forms, including insect larvae, annelids, turbellaria, and protozoa, were tested. In tests with H_2S all protozoa, regardless of their position in the saprobic system, had low resistance in the absence of oxygen. With 10 mg. of H_2S per liter, poly and alpha meso-saprobes resisted the poison for 14 hr. to 5.5 days; beta meso-saprobes for three to 13 hr.; and oligo-saprobes resisted for 1.5 to 6 hr. There was a clear relation between the effect of ammonia and the position of the organisms. The results suggest that the presence of poisonous products of decomposition would have the same effect on organisms of the unpolluted water zone as a reduction in the concentration of dissolved oxygen. Oxygen content would be the decisive factor in slow-flowing or stagnant water while poisons, especially ammonia, might be the main influence in polluted but rapidly flowing and therefore oxygen-rich water. Some organisms are, however, indicators of the presence of dissolved oxygen but not of the purity of the water.

Biglane and Lafleur (32) used bottom fauna in the classification of streams. Waste from a Kraft pulp and paper mill was toxic to Mayfly naiads and unionid clams while phenolic waste waters from a plant for creosoting wood eliminated crayfish, leeches, clams and snails, but sewage fungus, annelids and chironomids appeared in the area of greatest pollution. In a third stream high-salt concentrations, resulting from the discharge of brines from oil fields, were lethal to crustacea and many insects. The number and type of fish showed close correlation with the bottom fauna but some fresh-water fish showed adaptability to high concentrations of NaCl.

An extensive pollutional investigation was made of western Lake Erie during 1927 to 1929 (218). An index of pollutional conditions was set up. A mud bottom having less than 100 tubificid worms and more than 100 *Hexagenia* nymphs per square meter was considered free from pollution. Three degrees of pollution, based on numbers of tubificids per square meter, were recognized: light pollution, 100 to 999; moderate pollution, 1,000 to 5,000; heavy pollution, more than 5,000. While some areas of pollution were found near the Maumee and Raisin river mouths, it was concluded to be highly improbable that pollution in the western end of Lake Erie had been the controlling factor in depletion of the fishery.

Beck (28) proposes a simple biotic index for indicating biological conditions in Florida streams. The index may occupy any value ranging from 0 to about 40. The lowest value for a clean stream is 10. A grossly polluted stream will have an index of 0 and a moderately polluted stream 1 to 6.

Knopp (113) proposes a quantitative method for indicating biological conditions in the various zones of a polluted stream. His scheme is based on Kolkwitz and Marsson's classification and a survey of a long section of the River Main. For each station the number of organisms typical of each of the four pollutional zones is listed and the biological conditions of the station evaluated by means of a formula.

Sundene (188) sets forth the results of ecological studies of the algae of Oslo Fjord during 1940–42 and 1947–52. The inner basin receives untreated or coarsely screened sewage from Oslo and vicinity, which leads

to more general eutrophic conditions. Planktonic organisms thrive in the polluted inner areas causing a decrease in the transparency of the water and cutting off light from the sublittoral zone which has an extremely poor algal flora. Braarud points out (37) that oxygen deficiencies have been observed in the deep waters of Bonne Fjord, a branch of Oslo Fjord, and that deep-sea prawns and zooplankters have been killed. In the inner part of Oslo Fjord, cod have shown satisfactory growth but hatching of the eggs has been impaired. Gaufin and Tarzwell (80) describe environmental changes which take place in a polluted stream during winter. It was observed that stream flow is greater, metabolic activity is at a lower level, life zones become longer and diurnal variations in dissolved oxygen are at a minimum. Due to these changes, organic materials are carried farther downstream and the pollutional carpet of bacteria, protozoa and entrapped organic materials may extend to the clean water zone of summer, significantly reducing the macro-invertebrates which serve as fish food.

Wurtz (220) describes a modification of Patrick's method for the use of aquatic populations to indicate pollutional conditions. Illustrations of the use of the method are given.

Fish Kills

The dewatering of a clay mine at Conway, Pennsylvania resulted in an extensive fish kill in a 70-mile stretch of the upper Ohio River (9). Excess acid was blamed for the kill which was most severe in the East Liverpool-Wheeling area.

Release of irrigation water from Alcova Dam killed many aquatic insects and fish in the North Platte River (120). As the released waters moved downstream the color of the stream changed to yellow, then brown and finally grey. In 16 hr. the dissolved oxygen dropped from 9.3 p.p.m. to 0.3 p.p.m. Large numbers of dead insect larvae were noted on the water surface and the fish died in live boxes.

Water Quality Criteria for Aquatic Life

An increasing interest is being shown in water quality criteria for the protection and maintenance of aquatic life in our waters. The first progress report of the Aquatic Life Advisory Committee for the Ohio River Valley Water Sanitation Commission (16) sets up some base lines for the determination of criteria. A suitable habitat for fish is defined as one which produces a good crop as determined by census of catch, growth rate, condition and suitability of flesh. The range of pH in which direct lethal effects are not produced is indicated as 5 to 9.5, but it is pointed out that pH greatly influences the toxicity of some materials; that sudden changes are not desirable; and that, from the standpoint of productivity, it is best to maintain the pH in the range of about 6.5 to 8.2. For a well-rounded warm-water fish population, it is recommended that D.O. levels shall not be less than 5 p.p.m. for more than 8 hr. in any one day and at no time shall they be less than 3 p.p.m. It is recommended that the toxicity of wastes be determined by means of bioassays and that water from the receiving stream be used in determining the dilution needed for a particular waste.

Temperature

Gibson and Fry (83) report the upper lethal temperature for lake trout as 23.5° C. The temperature for maximum activity is from 15° to 17° C. Bailey (21) reported that a water temperature of 38° C. resulted in high mortality of fishes confined in a shallow pond. Symptomatic of distress was a marked lassitude, loss of orientation and reduction of swimming ability.

The immature fish were the most resistant, while among the different groups the cyprinodontid, poeciliid and centrarchid fishes were most hardy.

Dissolved Oxygen

Gibson and Fry (83) state that active respiration of one- to two-year-old lake trout becomes dependent on the oxygen pressure at approximately two-thirds air saturation. The minimum oxygen pressure for the species is approximately 40 mm. of Hg at 10° C. and 60 mm. of Hg at 20° C.

A laboratory study was made at the Hawaii Marine Laboratory on Coconut Island to determine the oxygen requirements of bait fishes, particularly the iao (157). Lethal D.O. levels and rates of oxygen consumption under various conditions were studied. Oxygen consumption showed an increase with increased flow and the critical oxygen level was between 1.5 and 2.5 cc. per liter. Individual iao showed marked differences in their resistance to D.O. deficiency, lethal levels ranging from 0.50 to 1.58 cc. per liter. At the higher temperatures, in the range from 19° to 29° C., there was a rapid increase in the rate of oxygen consumption and a more rapid reduction of dissolved oxygen to a lethal level.

Burdick (44) showed that young shad may be present at oxygen levels less than 4.0 p.p.m. This appears to indicate that previously published D.O. values, given as a minimum for young shad, may not be applicable to all natural waters. It is concluded that the minimum standard of 4.0 p.p.m. of dissolved oxygen for warm fishery waters is adequate for waters containing shad.

Wickett (214) reports the oxygen demand of sockeyed chum salmon eggs to be between 0.00013 mg. and 0.003 mg. per egg per hour at temperatures of 0.1° to 8.2° C. A high percentage of eggs was found dead in certain heavily silted areas of the creek. This may be explained by low concentrations of dissolved oxygen (0.2 p.p.m.) or low velocities of water in the gravel (2 mm. per hour).

It was determined experimentally (208) that certain marine animals show adjustments in their respiration; that is, oxygen consumption varies plus or minus proportionally with oxygen tension in the water. When the oxygen tension decreases below a critical value, utilization decreases rapidly and the animals die within a comparatively short period. It was shown that this critical point of the oxygen tension of the surroundings is very low for the inhabitants of D.O. poor areas, and highest for those living in well-aerated habitats.

Nikiforov (135) found the maximum assimilation of oxygen occurs in young salmon at about 22 days after hatching, after which a decline sets in, followed by a small increase at about 40 days. In a 50- to 60-day period a decided decline occurs (summer period) with a definite rise in 70 to 80 days. Differences in oxygen utilization (174) are also due to conditions in the habitat. At 20° C. the young of wild, large carp utilize 310 to 452 mg. of oxygen per kilogram of weight; mirror carp 220 to 260 mg.; and scaly carp 192 to 221 mg. Specimens from a water that is refreshed by flow show a substantially higher utilization than is displayed by specimens collected from ponds with relatively stagnant waters; the difference reached 50 per cent in extreme cases.

In experiments with trout in flows of water containing constant low D.O. concentrations (173) it was found that at temperatures of 9° to 10° C. young-of-the-year trout could withstand oxygen concentrations down to 1.9 mg. of D.O. per liter. The 50 per cent tolerance level was 1.75 mg. of D.O. per liter. Acclimation to low oxygen levels occurred: for a drop of 1.0 mg. of D.O. per liter in environmental D.O. concentration the tolerance level de-

creased by approximately 0.09 mg. of D.O. per liter and resistance times at given lethal levels increased up to five-fold. Between 20 to 33 hr. were required for the fish to acclimate to a change of 1.0 mg. per liter in the D.O. concentration of the environment. Acclimation to low levels of oxygen was accompanied by an apparent increase in the ability of the animal to remove oxygen at low D.O. concentrations. The tolerance levels of small fish were similar to those of large fish at similar acclimation levels.

Troiani (202) found that at 10° C. the average consumption of oxygen by *Gammarus pulex* is 1,350 cu. mm. per gram dry weight per hour. The intensity of respiratory metabolism increases with temperature to the lethal temperature of 30° C. and decreases with decrease in tension of D.O. below 3 to 4 cc. per liter.

Unusual thermal stratification was observed in Western Lake Erie during the period September 1–4, 1953 (40). Concentrations of dissolved oxygen as low as 0.70 p.p.m. were found near the bottom. Bottom samples collected on September 5, 1953 revealed a total of 465 dead *Hexagenia rigida* and *H. limbata occulta* nymphs per square meter. In 61 bottom collections made over a wide area between the Canadian shore and Catawba Island on September 14–26 and November 13, 1953 the average population of living nymphs was 44.3 per square meter, a great reduction. Bottom fauna collected from the same area in 1954 (39) indicated that a few nymphs were again inhabiting the area.

Studies were made of the oxygen requirements of six species of caddis flies from the River Blyth, Northumberland (149). Oxygen determinations showed little differences in D.O. in the swift-flowing shallows and deeper slow-flowing stretches. It was found that some larvae dependent upon current for feeding and larvae readily immobilized at a relatively high D.O. concentration in still water can tolerate low concentrations in flowing water. Current is therefore of prime importance in the distribution of larvae.

Job (104) made a detailed study of the oxygen consumption of brook trout. The consumption of wild and hatchery stock, ranging in size from 4 gm. to 1,000 gm., was measured after appropriate acclimation at 5°, 10°, 15° and 20° C. The periods of survival of rainbow trout in concentrations of un-ionized NH_3 in the range of 0.86 to 1.96 p.p.m. of N increased as the D.O. concentration was raised from 1.5 to 8.5 p.p.m. (66). At each D.O. concentration, the period of survival decreased as the concentration of un-ionized NH_3 increased from 0.86 to 1.96 p.p.m. The effect of a greater D.O. content in increasing survival time was greatest in the lower concentrations of un-ionized ammonia. Results of experiments reported by the Water Pollution Research Board (60) indicate that the period of survival of trout in a given concentration of undissolved NH_3 increases markedly with increase in the D.O. concentration. Thus any reduction in the D.O. content in a river may increase considerably the toxicity of NH_3.

Settleable Solids

Monthly bottom samples were collected from Shape Creek between October, 1952 and June, 1953 to indicate the effects of silting on the benthic fauna (193). Below the mouth of a tributary from an eroded area the population was 7.3 organisms per square foot while above it was 25.5 organisms. Studies in Oklahoma have disclosed similar effects of turbidity and silt (73). Nineteen paired ponds were studied and the findings showed that fish grew more rapidly in the clear ponds: bass increased 6.5 times over their beginning size in clear ponds; 4.0 times in intermediate ponds; and 1.25 times in muddy ponds.

Bass reproduced in 7 of 8 clear ponds; in 4 of 10 intermediate ponds; and in none of the muddy ponds. Plankton was 13 times and 1.5 times more abundant in the clear and intermediate ponds respectively than it was in the muddy ponds. These conditions are duplicated in the larger lakes. Fishing success is greater in the clear lakes.

Bioassays and Toxicity

Freeman (76) outlined the techniques employed in estimating the extent of pollution of surface waters by the discharge of trade waste waters, based on their toxicity to fish and other aquatic fauna. Bandt (22) gave a discussion on the application of toxicity bioassays in practical fisheries work, fish cultural activities and search for causes of fish kill. Leclerc and Devlaminck (119) described the equipment, type of fish, method of acclimatization and method of observation used in testing the toxicity of substances to fish. An attempt is being made to develop a standardized procedure to compare results of toxicity tests made by workers in Switzerland, France and Belgium.

Phenols

Trama (201) ran bioassays in a modified artificial dilution water to test the toxicity of phenol. Fish were transferred to new solutions every 24 hr. as the loss of phenol under test was about 2 p.p.m. in the first 24 hr. For bluegills the 48-hr. maximum toxic limit (TL_m) was 20.5 p.p.m. ± 2 p.p.m. and the 96-hr. TL_m was 19.3 p.p.m. ± 2 p.p.m. Fish reacted to all concentrations of phenol from 15 p.p.m. upward but did not react at 10 p.p.m. Survival for 96 hr. at various concentrations was as follows: 15 p.p.m., 100 per cent; 17 p.p.m., 70 per cent; 20 p.p.m., 50 per cent; 26 p.p.m., 10 per cent; and 28 p.p.m., all dead within 24 hr. In the Pliesse River below Leipzig when the D.O. content increased to 5.3 p.p.m. and the phenol content decreased to 4.3 p.p.m., the first protozoa and algae appeared and increased in variety and quantity as phenols were reduced to 0.2 p.p.m. (10). According to laboratory tests selected protozoa tolerated phenolic compounds up to the following concentrations in parts per million: phenol and cresols, 300; pyrocatechin, 150; resorcinol, 600; phloroglucinol, 650; pyrogallol, 33; hydroquinone, 6; and phenol waste concentrate, 13. Toxicity increased with temperature.

Bandt (23) reviewed the literature on the effects of phenol on fish and other aquatic life. He found that they were toxic, repelled fish, affected flavor, and killed fish food organisms. Pure phenol is lethal to trout at 9.5 p.p.m. and to tench at 12 p.p.m. It taints fish flesh at 25 mg. per liter while the level is 10 mg. per liter for cresol. These materials kill *Gammarus* at 25 mg. per liter and *Tubifex* at 200 mg. per liter. Data available in the literature on the toxicity of 15 other phenolic compounds are summarized. The author believes that the fish acquire the phenol taste from eating *Tubifex*. Tainting of fish flesh is most serious when there is an ice cover.

Meissner (129) reported on the toxicity of oxidation products of hydroquinone to protozoa bacteria, rotifers, crustaceans and mollusks. Relative toxicities as compared to phenol or several phenol derivatives are given in tabular form.

Ammonia

Bastos (26) reports that, in a 13-day test, NH_3 killed 47.8 per cent of "piabas" when present at 5.2 p.p.m. He states that size and weight do not influence the resistance to toxicity. In concentrations up to 30 p.p.m., CO_2 reduces the toxicity of undissociated ammonia by lowering the pH value of the water and thus increasing the degree of ionization of ammonia (60).

Insecticides

A synopsis of the papers presented at the 1955 American Chemical Society meetings contains much information on toxicity (3). Chlorinated benzenes are among the most troublesome materials. In California, fish have been killed by rice field application of Dieldrin at the rate of 0.5 lb. per acre. A concentration of 0.64 p.p.m. was found in surface waters and this was rapidly lethal, considering that 0.016 p.p.m. is significantly toxic. Other materials causing problems were toxaphene, D.D.T., and rotenone.

At 47° to 49° C. the 24-, 48- and 96-hour TL_m values of malathion to fall chinook salmon were as follows: 0.17, 0.15, and 0.12 p.p.m., respectively (145). It was further reported (105) that the toxicity of solutions of malathion does not change, at least during the first 14 days after preparation.

Investigations of the stream bottom fauna in a 52,000 acre watershed near Wilkes Barre, Pa., which received an aerial spray at the rate of 1 lb. of D.D.T. per acre, showed that the number and volume of benthic forms were rapidly reduced (98). Depopulation was not complete but some sensitive forms, such as the *trichoptera*, did not reestablish themselves for some time.

Two months after D.D.T. was sprayed over a forested watershed in New Brunswick for budworm control, fingerling salmon were virtually absent (215). Although heavy mortality followed the spraying, delayed action caused many deaths for a period of four months. Most of the immature stages of fish food insects were killed.

Hooper and Hester (100) report that bottom samples, taken in 36 North Alabama streams three years after an extensive kill due to cotton dusting with toxaphene and other insecticides, indicate that the toxicants were no longer present. Rotenone studies indicated a fish population made up largely of rough species.

When waste waters from a plant producing contact insecticides were passed through a sewage treatment plant, they eliminated the typical organisms of the filters, humus tanks and receiving stream (154). Even tubificids and chironomids were affected and fish showed effects specific for hexachlorcyclohexane.

Cyanide

Wuhrmann and Woker (219) report that with a decrease in oxygen tension the toxicity of CN increases at all temperatures. The temperature coefficient for the speed of action of CN is dependent upon concentration, while the retarding action of higher D.O. concentrations upon toxicity decreases with increasing concentrations of CN.

Renn (162) found that under conditions which prevent the loss of volatile toxic components young, fresh water fish react adversely to KCN concentrations exceeding 0.03 to 0.05 p.p.m. N as CN. Lactonitrile gave values only slightly less than those for KCN but the fish tolerated much higher concentrations of acrylonitrile.

Downing (65) found that the survival times of rainbow trout in KCN solutions in the range of 0.0105 to 0.155 p.p.m. CN increased with increase of D.O. concentrations between 10 and 100 per cent of air saturation values, the effect being most marked with the lowest concentrations of CN. Herbert and Downing (93) report in more detail on the survival of rainbow trout in KCN solutions.

The toxicity, to the western blacknose dace, of KCN and potassium cuprocyanide having CN to Cu M-ratios of 4.0, 3.75 and 3.0 were measured by a flow-through procedure (124). The toxicity decreased as the ratio of Cu to CN increased with the 24-hr. TL_m for KCN and the 4.0, 3.75 and 3.0 M-ratios being 0.22, 0.38, 0.47 and, 0.71 p.p.m., respectively. In spite of the decrease in toxicity due to the presence of Cu, cuprocyanide solutions are suf-

ficiently potent to constitute a pollutional hazard when present in industrial wastes.

Other Materials

Tests of the relative toxicity of the various members of the homologous series of alkyl-dimethyl-benzyl-ammonium-chlorides to sockeye salmon indicated that toxicity rises with the increase of chain length to a maximum with the hexadecyl homologue and drops off somewhat with the octodecyl homologue (171). Four tables are given showing the toxicity of the various materials to fish.

The toxicity of slime control agents to *Notropis atherinoides* and *N. cornutus* were determined and related to their bacteriostatic and fungistatic properties (207). The minimum lethal concentrations in parts per million of the various substances were reported to be as follows: BSM 11, 0.8; Buffen 30, 0.02; Butrol, 0.5; Dowicide G, 0.05; Pyridylmercuric acetate, 0.15; Pyridylmercuric chloride, 0.04; and Roccal, 10.

Toxicity tests (11) showed that automobile gasoline and jet aviation fuel are more toxic to salmon fingerlings than diesel-truck oil and sludge oil. Surface films of the first two were lethal at 5,000 and 10,000 p.p.m. while agitated solutions were lethal at 100 and 500 p.p.m. respectively.

The high content of magnesium salts and chlorides discharged from a potash works killed fish and exercised a selective effect on the benthic fauna of the Werra and Wipper (1). The gammarids and the small organisms are the most sensitive and were eliminated first. The increase in salt content resulted in a population consisting of 90 to 98 per cent *Chironomid* larvae and resulted in a population with few species but large numbers of individuals. The saprobic system was still recognizable till a chloride concentration of 3,000 p.p.m. was reached.

The toxicity of rotenone to six species of fish was studied by Burdick, Dean, and Harris (45). Toxicity curves were constructed for comparing the effect of temperature, pH and variations between species. A wide variation in the exposure required to kill was found in the six species. These are in the order of their resistance: brook trout, rock bass, creek chub, smallmouth bass, common sucker and brown bullhead.

Microbiology

Dauer and Sylvester (56) reported only four disease outbreaks for which there was good evidence that water was the vehicle of infection. There were also three other outbreaks in which water was suspected as the source of infection. One of the four water-borne outbreaks was typhoid fever in a coal mining village where water was pumped from a worked-out mine into a distributing system of the town. Two outbreaks of gastroenteritis were reported. The three outbreaks of suspected water-borne origin were also gastroenteritis and occurred following consumption of water of doubtful sanitary quality.

Archer (17) has described an epidemic of infectious hepatitis in a military camp in Hong Kong thought to be due to contamination of drinking water with polluted river water. The hazards of a dual system of water supply were emphasized. A water-borne outbreak of amebiasis was studied in South Bend, Indiana (42)(71)(137). Siphonage of raw sewage into the supply line of a private water system was blamed for the outbreak. A leak sufficient to allow sewage contamination was found in the plant water supply suction line between the storage tank and service pumps, at a bell and spigot box on a plant sewer line. Previous difficulties with coliforms in the drinking water had been "corrected" by chlorination (0.3 to 0.4 p.p.m.).

To determine the importance of canal water as a source of infection by

Salmonellae in Mendoza, Argentina, 58 water samples were examined by Pallazzolo, Ansiaume, Leiguarda, and Peso (142). *Salmonellae* were isolated from 82.8 per cent of the samples. Of the 11 species found in water, the six occurring most commonly were also isolated in approximately the same proportions from children exhibiting enteric disorders. Ferramola *et al.* (72) examined 481 water samples from the Mendoza River (Argentina) and found 31.3 per cent to contain *Salmonellae* of 15 species. No relation was observed between the occurrence of *Salmonellae* and the numbers of coliform bacteria in the samples examined. Six weeks after an epidemic of intestinal disease, Kroger (115) isolated *S. bareilly* from samples of sewage (Luneburg) and sludge, and on vegetables from the irrigation fields. Steiniger (185) reported that sea birds continued to excrete typhoid and paratyphoid bacteria even after long separation from the polluted water where they were infected. He described the transmission of typhoid and paratyphoid infections by polluted cistern waters collected from roofs, and discussed the part played by birds in this pollution.

Ljutov (126) found that concentration of bacteria by filtration through "Supercel," followed by incubation on solid media, was a better method of isolating *Salmonellae* than previously used methods. As few as five or six pathogenic microorganisms could be detected in 20 l. of tap water. A selenite brilliant green enrichment medium for the isolation of *Salmonellae*, which has the advantage of being more effective in preventing the growth of *Escherichia* and *Proteus*, has been developed by Stokes and Osborne (186).

Pathogenic *E. coli*, types 0-111 and 0-55, were recovered by Monnet *et al.* (133) from drinking water supplies in France. *E. coli*, type 0-111:B4, was found in main water along with other bacterial evidence of pollution following a breakdown in chlorination. *E. coli*, type 0-55:B5, was isolated from shallow well water accompanied by other signs of fecal pollution. Finding pathogenic serotypes of *E. coli* in main water indicated the necessity of installing adequate treatment to protect consumers from such risks.

Larson, Wicht, and Jellison (118) isolated "a new organism" from a water sample collected in Ogden Bay, Utah. This microorganism, designated *Pasteurella novicida*, closely resembles *P. tularensis* in gross appearance of cultures, microscopic appearance and pathogenicity. It may be distinguished from *P. tularensis* by fermentation studies and serologic tests. An epizootic of tularemia in beavers and muskrats of Waterton Lakes National Park, Alberta, was studied by Banfield (24). This seemed to be the first time that *P. tularensis* has been demonstrated in the natural waters of Canada. The height of the epizootic appeared to have been in the autumn, judging by the presence of unutilized feed beds and the first discovery of carcasses. There were no known human cases of tularemia associated with the outbreak.

Two cases of primary tuberculosis following immersion in sewage contaminated water were reported by Miller and Anderson (131). These cases occurred in children, aged 4 and 2½ years, in northeastern England. The authors reviewed five similar cases from Scandinavia and several papers showing that *tubercle bacilli* can be recovered from sewage effluents in spite of chlorination.

Rendtorff and Holt (161) have shown that, experimentally at least, cool drinking water is a relatively efficient medium for the transmission of *Endamoeba coli* and *Giardia lamblia* cysts. Infections with both species occurred during all periods tested up to 16 days storage. *E. coli* produced infections in 70.6 per cent of the volun-

teers and *G. lamblia* produced infections in 64.7 per cent. These experiments were designed to simulate natural transmission of intestinal protozoan parasites.

Three species of potentially pathogenic fungi have been repeatedly isolated by Cooke and Kabler (53) from polluted water and sewage in southwestern Ohio. *Allescheri boydii, Aspergillus fumigatus* and *Geotrichum candidum* appeared to be normal inhabitants of sewage and polluted stream waters. Becker and Shaw (29) studied the fungal flora of sewage treatment plants receiving domestic sewage at Moscow, Ida. and Pullman, Wash. On the basis of effluents, they concluded that most fungi do not multiply in sewage treatment systems; the data presented appear incomplete, however.

Stokes (187) described morphological and physiological characteristics of the filamentous sheathed bacterium *Sphaerotilus natans* commonly isolated from stream, pond and ditch waters. Drumond and Postgate (69) reported a procedure for the estimation of sulfate-reducing bacteria and showed that chromate is a promising specific agent for preventing the nuisance caused by them. Klyunkov, Rogovskaya, and Shneerson (112) found that a culture of phenol-destroying bacteria could not be maintained in pure state under conditions of use in coke-chemical plants. Because the chemical content of phenolic waste liquors varies considerably, the use of a single bacterial culture did not appear to be practical. Rogovskaya (168) has also discussed the influence of aminocarboxylic acid lactams on microorganisms in water and on the biochemical processes in self-purification of water.

Peso and Mignone (147) investigated the use of bacteriophage as an index of water contamination. They found the bacteriophage technique not superior to the usual bacteriological methods for detection of water pollution. Gilcreas and Kelly (84) examined the relation of coliform organism test to enteric virus pollution. Their experiments indicated that effective and complete treatment of water was necessary to insure safety from potential pollution by enteric viruses. It seemed safe to state that the coliform index is still a reliable indicator of significant pollution and of the effectiveness of standard water supply treatment.

Kelly, Clark, and Coleman (109) demonstrated the greater effectiveness of gauze pad "swabs" as compared to catch samples for collecting sewage specimens for the isolation of infectious agents. Observations relative to *Coxsackie viruses, tubercle bacilli, S. typhosa* and *S. montevideo* isolations were included. The studies indicated that sewage treatment, while complying with existing standards, may not control pathogenic microorganisms to the extent that receiving streams can be ignored as potential sources of infection.

Working at the South District Filtration Plant, Chicago, Vaughn and Scarce (209) supplemented the traditional methods of identifying "lactose-positive" organisms by electron microscope techniques. Twenty-three bacterial strains were isolated from presumptive tubes showing gas. These strains were identified as: *Bacillus cereus; B. cereus* var. *mycoides; B. subtilis; B. circulans; Micrococcus candidus;* and *Mic. aurantiacus.* In a study of additional methods for bacteriological analysis of water, Cope, Dempster, and Chapin (54) found a tetrathionate MacConkey-Kligler system to yield three times as many positive coliform tests as Standard Methods procedures. A second series on well water indicated that the use of violet red bile agar gave a higher per cent of positive coliform tests than Standard Methods. Pederson and Skinner (146) compared the productivity of standard lactose broth with

lauryl sulfate broth and with the Eijkman methods for demonstrating fecal coliform bacteria. Under the conditions of the tests, neither lauryl sulfate broth nor the Eijkman method was more efficient than lactose broth in eliminating false positive coliform tests when dilutions of feces were used as inocula. Eijkman broth at 45.5° C. did not inhibit all strains of Aerobacter in feces. Taylor (192) found that a 6-hr. incubation period in brilliant green bile broth and MacConkey's confirmatory media yielded about 95 per cent of positives obtained after 24-hr. incubation. Hendrickson (92) compared the efficiency of several methods for detecting coliform bacteria in water. He found that gas production was delayed in MacConkey broth as compared to lactose peptone broth, but that false positives due to Gram postive bacteria were only one-half as frequent. Frequency of false positive reactions due to Gram negative bacilli failing to produce gas from lactose was very high. Hajna and Damon (86) proposed the use of a buffered desoxycholate glucose broth for primary inoculation followed by buffered desoxycholate lactose broth for confirmation of coliform organisms instead of Standard Methods media. The data presented indicated a superiority of this procedure over present Standard Methods. Thomas *et al.* (198) reported that the flaming of taps before sampling caused no significant differences in the most probable number of coli-aerogenes organisms or of *B. coli* in water samples. Thomas (194) and Pomeroy (151)(152) discussed statistical treatments of bacterial data. It was believed that the arithmetic mean coliform density, as calculated from a series of M.P.N. values from multidilution tube tests, was a more valid measure of hazard due to enteric pathogens than either the geometric mean or median.

Fischer (75), and Thomas and Hobson (196) pointed out the similarities of intermediate coliform organisms from animal intestines and from the ears and panicles of cereal crops to other coliform organisms usually considered to be indicators of pollution. Thomas *et al.* (197)(199)(200) studied the bacteriology of farm water supplies in England. The majority of 311 water samples examined contained coliform organisms, a large number of which were *E. coli,* type I. Overnight storage of such water samples, even at 0° to 5° C., may cause significant changes in bacterial content and can result in acceptance of supplies not really safe. Samples should be examined within 6 hr. after collection and should be kept at less than 5° C. during transportation. Levine, Tanimoto, Minette, Arakaki, and Fernandes (121) suggested a boric acid lactose broth medium in conjunction with brilliant green bile broth as a good method for simultaneous confirmation of coliform and *E. coli* indices from positive or doubtful lactose broth presumptive tubes.

Litsky, Mallmann, and Fifield (125) compared the most probable numbers of *E. coli* and enterococci at 14 stations on the Connecticut River near Northampton, Mass. The final mean ratio of *E. coli* to enterococci was 1 to 7.6 as compared with previously reported ratios of 13.3 to 1 and 63 to 1. It was suggested that the reason for the low numbers of enterococci recovered from sewage and polluted waters by previous methods is not due to their numbers but rather to the failure of the media employed. Dresscher (67) described a liquid thallium sulfate medium for the enumeration of streptococci in water. The test is simple to carry out and takes less time than other means of identifying streptococci because it is not necessary to make a microscopic examination. Slanetz, Bent, and Bartley (176) developed a new medium for use in conjunction with the membrane filter method for enumerating enterococci in

water. In tests with water samples from one reservoir and six rivers, the membrane filter method consistently yielded higher enterococci counts than the Winter-Sandholzer method and the counts in all but three samples were higher than those obtained with the method of Litsky. DeLaney (59) stated that the available data do not warrant the aceptance of the enterococcus group as an adequate indicator of bacterial quality for finished drinking waters. However, he believed that the group would be an excellent indicator of the degree of pollution in such samples as polluted rivers, irrigation water, bathing areas and shellfish.

Karakasevic (107) examined 450 water samples from heavily polluted, moderately polluted and drinking water sources by tube methods using several media, and by the membrane filter procedure (M.F.). He concluded that membrane filtration is more dependable and more exact for establishing presence of coliform organisms in water. Taylor, Burman and Oliver (191) applied the membrane filter technic to the routine bacteriological examination of water. They obtained higher coliform counts with the membrane filter than with their tube tests. However, the tubes were incubated at 42° C. for 18 hr., followed by 6 hr. at 37° C. Therefore, the conditions of the tests were hardly comparable. Slanetz and Bartley (175) found that results of tests for coliform densities by the membrane filter technic were in good agreement with results obtained by the Standard Methods M.P.N. procedures for samples of river and reservoir waters. Of 193 colonies with a sheen isolated from the membrane filter, 97 per cent were confirmed as coliforms, and 58 per cent of these colonies were identified as *E. coli* by IMViC reactions. Results of investigations by McCarthy (128) indicated that discrepancies between membrane filter and tube technique appeared to increase with time and distance from fresh pollution and that the difficulty of recovering coliforms on the membrane filter increased as the ratio of non-coliform to coliform became greater. He believed that the most urgent need in connection with the membrane filter seemed to be the formulation of a more satisfactory medium. Geldreich *et al.* (81) developed a delayed incubation membrane filter test for coliform bacteria in water. Estimations of coliform densities in water by the delayed membrane filter technique at 13° to 32° C. indicated good agreement with the M.P.N. on stored liquid samples at 5° C. The membrane filter storage results at room temperature and at 35° C. were superior to results of M.P.N. procedures on liquid samples stored 24 hr. or longer at room temperature or 35° C. Results of statistical analyses by Thomas and Woodward (195) of three extensive investigations on a wide variety of natural waters comparing the M.P.N. and membrane filter techniques indicated that the former gave higher estimations of coliform density by a factor of 1.0 to 1.9 with an average of 1.3 for the specific techniques used. The disparity between membrane filter and M.P.N. values for most of the water samples tested was not significantly larger than discrepancies between results obtained with permissible variations of the standard dilution method. Lieber (122), Bush (46), and Bliss, Steinmetz, and Witt (35) have reviewed the development of membrane filter technics and pointed out the advantages and disadvantages attributed to the procedures.

Meleney (130) suggested that the control of schistosomiasis presented problems related to the life cycles of the three species infecting man and related also to the various snail vectors, the customs of the human hosts, and the variations in environment. He concluded that each endemic area must be studied individually and that a

combination of methods, devised by a biological team, will be necessary to bring progress in control. Chang *et al.* (49)(50)(51) have shown that *E. histolytica* cysts survive in distilled water at 0° C. as long as 62 days. They also reported that the destruction of amebae cysts by iodine and silver nitrate is a rate process of the first order and that the poor cysticidal activity of silver nitrate as compared with iodine is probably due to the poor penetrating power of silver ion into the cysts. Tri-iodide was much inferior to I_2 in cysticidal efficiency. Hannig (90) used bleach liquor successfully in the control of fungi and algae in cooling tower water. After six months of using 8 gm. of chlorine per cubic meter, surfaces were clean and the turbine efficiency was markedly improved. Popp (153) has restudied the effect of chlorine for the disinfection of water. Many tests were made using chlorine contents up to 0.6 p.p.m. from various chlorine sources and at different pH levels and bacterial loadings up to 10^8 organisms per milliliter. His results indicated that the reduction of organisms did not follow exponential law but occurred in two steps. First step was rapid reduction of organisms, lasting about 12 sec. This was followed by a secondary slow reduction. The killing action of the chlorine was used up during the initial contact period. Polster and Bochorak (150) investigated the use of solid compounds of hydrogen peroxide in the disinfection of water. One compound produced complete disinfection after 20 to 30 min. when present in concentration of 0.1 per cent and after 2 hr. in a concentration of 0.01 per cent. Chambers *et al.* (48) showed that many natural waters interfered with the bacteriocidal action of quaternary ammonium compounds. Bicarbonates, sulfates and chlorides of calcium and magnesium appeared to be the primary cause of interference. Sodium and potassium bicarbonate did not seriously interfere. Hoather (97), Schmidt, Moller, and Thiele (172), and Ricks *et al.* (166) reported that water can be treated adequately for drinking purposes by ultraviolet radiation, provided the water has proper optical density and that sufficient energy reached all the water treated. Technical details relative to wave length, light source, dosages, and penetrability were discussed.

Berger and Stevenson (30) summarized the feasibility of biological warfare against public water supplies and the nation's ability to prevent or to recognize and ward off an attack. A wide variety of potential agents are available to an enemy, including several not normally associated with drinking water. The distribution system appeared to be a more attractive target than the source of supply. They believed logistics would present no great difficulty. Several recommendations were offered for improved protection of public drinking-water supplies against enemy use of biological warfare agents.

Chemistry

Gloyna (85) presented a review of the effect of laundry wastes on settling, foaming, aerobic and anaerobic processes. The review appears to be directed primarily at problems presented by laundry wastes from Atomic Energy Commission installations.

Hammerton (89) studied the interrelationship of chemical structure of synthetic anionic detergents and their susceptibility to bacterial degradation. Materials containing branched alkyl groups were quite resistant to destruction, whereas straight chain compounds were readily degraded. Major differences in bacterial resistance were not attributable to sulfate and sulfonate groups. Further study of pure materials having various structures was recommended as a basis for further definition of the interrelationships

between structure and susceptibility to biochemical attack.

Smith and Subby (178) considered the problem of removal of fertilizing minerals attributable to sewage from lake waters. While organic materials are destroyed, mineral enrichment tends to be cumulative. Land irrigation and holding lagoons, followed by filtration, were discussed as mineral control procedures for effluents.

Wedgewood (211) has made further investigation of the composition of sewage and trade effluents. He reports that acids are a major portion of the organic material in effluents. In one effluent, free of gas liquors, 0.4 p.p.m. of phenol is reported.

The interrelationship of biological populations, dissolved oxygen, and phenol content in the River Pleisse was studied over a nine-months period (10). Certain forms were found highly resistant to phenols. Supplementary laboratory studies of biological resistance to specific phenols are also listed.

Gameson (77) reported studies of self-purification in estuaries. Over-all oxygen transfer was the important factor, with atmospheric oxygen the principal source. In addition to indirect estimation of oxygen transfer by substrate analysis a direct measure of oxygen absorption was attempted by observation of the change in composition and volume of a portion of air held in direct contact with surface area.

Oxygen Sag and Self-Purification

Both laboratory and field studies to measure rates of atmospheric reaeration of water have been performed by a group of English investigators. Downing and Truesdale (64), in a series of laboratory experiments, studied the effects of mixing, surface wind, waves, temperature and surface contaminants (oil, detergent) on rates of reaeration. In these studies, reaeration rates are expressed in terms of an "exit coefficient" (f) defined as

$$f = \frac{V}{A} K$$

where A is the exposed surface area, V is the volume undergoing reaeration and K is the reaeration constant as usually used in the oxygen sag expression. The exit coefficient is defined as "the rate of change of oxygen concentration in unit depth of water when the saturation deficit is unity," and the dimensions suggested are centimeters per hour.

Mixing was accomplished by stirring the water in the laboratory tank. The exit coefficient increased linearly with the rate of stirring up to rates which caused the formation of vortices, after which it increased more rapidly. Surface wind effects were studied by use of a fan whose air stream was directed across the water surface. Both distilled water and sea water were used. In general, wind had little effect until a wind velocity of about 10 f.p.s. was exceeded, after which the exit coefficient increased sharply with increasing wind speed. The appearance of the water surface remained unchanged until the wind velocity reached 10 f.p.s., after which the formation of wavelets and ripples was noted. The authors have indicated here that their laboratory results do not agree with measurements in an estuary. In the latter case, there was a gradual steady increase in rate of reaeration up to wind velocities of about 35 f.p.s.

Heavy fuel oil in thicknesses greater than 10^{-4} cm. materially reduced reaeration, causing the exit coefficient to be reduced by a factor of 4 at an oil thickness of 1 mm. A similar effect, though not as strong, was observed for a light spindle oil. Surface wind with a velocity of 27 f.p.s. greatly enhanced reaeration in the presence of the light oil. Rates of solution were also reduced somewhat in the presence

of 1.0 p.p.m. of an alkylbenzenesulfonate, a soluble surface-active agent.

Field studies of the effects of reaeration of anionic synthetic detergents were performed in a small creek by Gameson *et al.* (79). Reaeration rates, as exit coefficients, were determined from measurements of dissolved oxygen (Winkler method) at successive downstream locations, after initially deoxygenating the creek water by use of sodium sulfite. This technique is referred to as "direct" reaeration measurement in the sense that the creek was unpolluted by organic wastes and no significant B.O.D. was encountered. In the absence of detergents it was noted that the exit coefficient (f) varied directly with the stream discharge. The presence of detergent, in concentrations up to 2.0 p.p.m., reduced the rate of reaeration by as much as 40 per cent, but there was no apparent relation between f and the concentration of detergent.

The foregoing paper is of interest in that it considers gasometric methods for measuring reaeration rates, and describes both laboratory and field equipment designed for this purpose. Gasometric methods involve enclosing a portion of air over the water surface and measuring changes in the oxygen content of this air over a period of time. It is pointed out by the authors that any such direct method interferes with movement of the water surface under the enclosing device, leading to false results. Early experiments with gasometric equipment were not as successful as had been hoped, but several means of improving the experiment are suggested.

Measurement of the saturation concentrations of oxygen dissolved in fresh water and sea water in the temperature range 2° to 35° C. are reported by Truesdale *et al.* (203), and by Gameson and Robertson (78). Dissolved oxygen was determined by the Winkler method, and saturation was usually approached from below. Care was taken to avoid supersaturation. The measured saturation concentrations for pure water were lower than those given in Standard Methods by as much as 0.4 p.p.m. Saturation values for sea water are also given and compared with other published values.

Self-purification of natural waters has been the subject of several papers (77)(114)(62)(163) and rather general discussions of some of the factors involved in self-purification have also appeared (96)(36). Another simplified version of oxygen sag analysis has been attempted (165).

Buswell (47) indicates that the B.O.D. test does not give adequate information with regard to measuring the "total load" on a stream due to waste discharge. He suggests that adequate measurement of the waste load requires determination of the conventional B.O.D., total carbon, one or more C.O.D.'s, ammonia nitrogen and the concentration of nitrosomonas organisms in the stream. Aside from the large additional laboratory work load involved, this suggested series of determinations does not mention the need for B.O.D.'s measured at times earlier than five days, and for the use of river dilution water and seed if it is desired to know the actual effect of the waste in the stream to which it is discharged.

The effects of several seed materials on the rate of biochemical oxidation have been studied by Gellman and Heukelekian (82). Several industrial wastes as well as four of the alcohols were tested with four different seeds, including normal sewage, normal activated sludge, acclimatized activated sludge and dispersed growth aeration seed. Acclimatized activated sludge was the most effective seed, while normal sewage was least effective. Oxidation rate constants greater than 1.0 are reported for certain industrial wastes with acclimatized activated

sludge seed, as compared to values of 0.1 using normal sewage seed.

Regarding the practical value of acclimatized seeds, these authors state that the ease with which acclimatization is accomplished suggests that such seed should be more widely used both for waste load measurement and process control (where biological aeration is used as the treatment process).

That regulation of stream discharge for purposes of power development need not adversely affect a stream is pointed out by Mohler (132), who discusses the results of this practice on the Aare River. In that case no adverse effect has been noted, either in terms of dissolved oxygen or the biological history of the stream. Alter and Porter (2) have reported the results of a one-year water pollution survey in Alaska, including evaluation of the asset and liability factors in self-purification.

Surveys and Studies

Articles concerning pollution of coastal waters, harbors, streams and ground water have been presented.

Nusbaum, Miller, and Reinhardt (136), summarizing data from several sources, discussed the distribution of pollution within the surf zone along the California coast. Water movement within the surf zone is characterized by currents parallel to the shore. They may travel in either direction and may shift from one direction to the other. Pollution discharged into the surf zone will be laterally distributed along the shore, affecting beneficial water uses. Beyer (31) studied the effects of tides, currents, density and winds on the dispersal of sludge from primary sewage treatment dumped into Oslo Fjord, Norway.

Davis (57) described methods used in the plankton study phases of a pollution survey in the Cleveland Harbor area of Lake Erie and discussed results of the study. He concluded that plankton methods do not provide a reliable index of pollution in localities such as the one investigated and that other available methods are much more sensitive and more easily performed. Filice (74) examined the effect of pH, salinity, oxygen content and presence or absence of industrial and domestic waste on the invertebrate bottom fauna of the San Francisco Bay area. Sewage is not as detrimental to volume of fauna as industrial wastes and actually enriches the water outside the zone of greatest toxicity.

Pollution in the Alzette River in Luxembourg was investigated by Krombach, Barthel, and Molitor (116). They report rates of biochemical oxidation for the length of river studied. The transport of solids in the Meuse River during a severe flood was studied by Beaujean and Leclerc (27). They found that more than 50 per cent of the suspended matter carried annually by the river was transported during the course of this month-long flood. The presence of copper in water used for irrigation from the Watarase River (Japan) was found to have a detrimental effect on the growth of rice in studies carried out by Deguchi (58). An investigation of diffusion of effluent from a submerged industrial waste sewer in the St. Lawrence River near Maitland, Ont. is described by Reid (159). The objectives of the investigation were to confirm that conditions in the river were satisfactory and to obtain general knowledge of the diffusion pattern. Initial work established that an investigation such as this in the St. Lawrence River was extremely difficult. Detailed planning was then made for an elaborate test. Dye was added to the effluent to permit visual observations. A diver was used to establish the trace of the effluent downstream. Direct measurements of waste concentration were made by use of a conductivity meter (the effluent was an electrolyte). Chemical measurements were made on samples taken

simultaneously with conductivity readings.

Halluta (87), in studies on the lower reaches of the Rhine River, found that objectionable taste and odor of bank-filtered water obtained from nearby wells were apparently the result of the passage of phenols and organic acids through the banks.

Abatement and Control

Legal aspects of abatement and control of pollution continues to be of concern to water users with varied interests. Owen (141) discusses control of stream pollution under the basis of riparian rights by means of court suits for damages or injunctions. In general, the preferred method is by injunction as it provides preventive relief instead of a payment for damages incurred after the fact. Certain limitations to the use of injunctions are listed and the doctrines of balancing of equities and of convenience are discussed with illustrations from court cases.

Cleary (52) describes in detail some of the policies, practices and problems encountered in the control of pollution in England and Germany. Dornheim (63) describes the powers and duties of the River Boards in England as stated in the Rivers' Board Act of 1948 and the Rivers' (Prevention of Pollution) Act of 1951. The author presents the differences in duties and powers between the English River Boards and the various associations in Germany. The desirability of forming boards on the English model is discussed. The problems of international rivers are considered. Evans (70) discusses the legal aspects of pollution in the United Kingdom as related to common law, the Rivers' Board Act of 1948, and the Rivers' Act of 1951. Lovett (127) records the history of the development of pollution abatement measures for England and Scotland. Heaton (91) briefly discusses legislation relating to the control of pollution of surface waters in Great Britain and describes the effects of pollution by sewage, trade waste waters, agricultural wastes and storm water. Kempf (111) presents information relative to judicial, administrative and legislative aspects of the control of pollution of surface water by trade waste waters in France. Legislation relating to fisheries and to municipal and industrial water interests is reviewed. Some recent administrative documents and a list of judicial decisions are appended.

The application of stream standards and classification, as they may relate to the abatement of pollution, are discusse by Hess (94). This author has presented information for allocating the absorptive power or capacity of a stream to assimilate pollution from existing industries and to care for projected industrial expansion. Consideration is given to the assimilating capacity of a stream during critical low flows in relation to factors of safety. Kay (108) stresses the need for a precise policy to be adopted to control the physical, chemical and bacteriological qualities of surface waters relating to municipal and industrial pollution in Manitoba, Can. Southgate (181) presents a general discussion of water quality standards including pH, suspended solids, D.O., B.O.D., temperature, organic carbon, C.O.D., color and immiscible liquids. Consideration is given to the suppression of natural purification by pollutants. Fish toxicity tests are discussed in some detail.

The integrated plan of waste treatment as related to other water uses, including potable water supplies, is described by Rohde (169) for the Ruhr District of Germany. In 1952, 270,277,000,000 gal. of water from the Ruhr River was used to supply a population of 4,500,000 in addition to the industries. The high consumption necessitates strict enforcement of regulations concerning reservoir construc-

tion. Sewage and waste disposal regulation, which includes diversion of water to the Rhine River, is rigidly enforced. High-rate trickling filters are planned for sewage treatment. Treatment to reduce phenols and acids from pickling liquors is rigidly enforced. The Ruhr Association operates 80 sewage treatment plants, 25 pumping stations, 4 reservoirs, and 48 industrial waste treatment plants, with associated waste collection systems 155 miles long. The reservoirs are equipped with barge locks and are available for recreation. Similar plans for integrated water uses have been developed for the Emscher River.

Financing sewage disposal and water treatment installations on the Thames River, Eng., are discussed (8). Projects that are approved are supported by the Ministry of Housing and by local governments.

Industries' interest in abating pollution is evidenced in articles relating to the construction of waste treatment facilities. Black (34) outlines varied liquid-waste problems of industry and presents several examples to illustrate present thinking on treatment practice. Types of treatment of wastes are described for the following industries: petroleum refining, automotive, paper, petro-chemical, steel, metal plating, textile, tannery, dairy, food processing and meat industries.

Pettet and Ware (148) discuss treatment of cyanide wastes by biological systems. They state that up to 1 to 2 p.p.m. of cyanide can be tolerated by biological treatment systems. It is recommended that direct stream disposal should be avoided.

Horner *et al.* (101) discuss the use of electrolysis in relation to waste pickle liquor. Such liquor is subjected to electrolysis across an anion-exchange membrane. Sulfuric acid is collected on one side of the membrane and electrolytic ion is deposited at the cathode on the other side. The costs are comparable to lime neutralization.

A number of articles dealing with the treatment of textile wastes have been published. A bibliography on textile mill wastes was compiled by the Stream Sanitation Committee of the Piedmont Section of the American Association of Textile Chemists and Colorists (5). Included is information relative to textile waste properties, waste reduction and prevention, waste treatment, legal requirements, economics of treatment and disposal, and general information on industrial waste control. An industrial waste guide to the wool processing industry has been published (4). Steele (184) outlines the progress the textile industry has made in recovering caustic. The experience of several bleacheries is given, exemplifying the practicality of recovering caustic and thus alleviating pollution. Stafford and Northup (182) present data of the 5-day B.O.D. for about 154 textile chemicals, as an aid to textile mills interested in careful and controlled disposal of chemical wastes to minimize stream pollution. Brown (43) presents data from a two-year study of bleaching and dyehouse wastes. Souther and Alspaugh (180) report on pilot-plant studies using mixtures of domestic sewage and textile mill dye and finishing wastes by high-rate trickling filters, by activated sludge and by chemical treatment. The purpose of the studies was to determine the most efficient and economical method for treating such wastes. In contradiction to published reports stating that sewage and industrial wastes with high alkalinity cannot be treated successfully in an activated sludge plant, results from the authors' research indicate that pretreatment by trickling filters and subsequent treatment through activated sludge is a most efficient method. An unusually high B.O.D. and color removal is obtained. Snyder (179) discusses the problem of stream pollution resulting from discharge of process wastes from Crompton-Shenandoah's dyeing and

finishing plants. Consideration is given to the steps taken toward solving the problem by substituting synthetic, film-forming compounds for natural sizing materials. The possibility of reducing over-all pollution from cotton dyeing and finishing plants by as much as 70 per cent is indicated, through the use of chemical substitutions. Smallhorst (177) presents a brief and condensed report on the activities of the Texas State Department of Health in determining methods of treating textile mill wastes to render them suitable for discharge into a municipal sewerage system.

Pulp and paper mill wastes are reported as having been reduced by activated sludge treatment at Jackson River, Va. (6). By the addition of nitrogen and phosphorous to activated sludge, organisms develop which are effective in reducing the effluent B.O.D. from 140 to 15 p.p.m. With such treatment, now removing oxygen demanding wastes from the stream, fish have moved 20 miles upstream from their former limited range. Webster (210) presents information relative to the use of natural ponds and creeks as waste treatment facilities by the National Container Corp. at Valdosta, Ga. Wetherhorn (213) gives a report on reductions in effluent B.O.D., brought about by changes in the recovery system of the Southern Paperboard Corp. at Port Wentworth, Ga. Surveys were carried out prior to and during the incorporation of changes in the waste disposal system. Survey data are presented.

The creation of new pollution is pointed out by Lang (117) who discusses air pollution corrective measures as they may complicate water pollution control problems. Only 5 per cent of the papers reviewed on wet methods of air pollution control made reference to the effect of the method on water pollution. Scrubbing and absorption methods of air pollution control result in sludges, wash water, filter cake and froth which, if discharged to streams, are likely to produce water pollution problems. Disposal of relatively dry concentrates by burial, with recycling of liquid treating agents, should be preferred over disposal of such wastes in a stream. Both the engineer and control officials should consider carefully the interrelationships between water and air pollution control.

Stream Standards

Weir (212), Rhame (164), and Hubbard (102) discussed the classification of streams in Georgia, South Carolina, and North Carolina respectively. Young (221) outlines the cooperative program of the U. S. Public Health Service in pollution abatement. Georgia does not classify streams in the usual sense whereas formal classification of streams is a part of the pollution control procedures in both of the Carolinas.

Bacon and Sweet (18) and Rawn and Bacon (158) described the four-step process by which water quality criteria are set and waste discharges are controlled in California and discuss the relationship of these water quality criteria to the over-all California water plan.

Powell (156) has described the varying principles employed in different states in classifying streams.

Mueller (134) concluded that in order to avoid excessive growth of algae and aquatic weeds nitrate N should be kept below 0.3 mg. per liter and total N below 0.6 mg. per liter.

The Bi-State Development Agency in its report on pollution of the Mississippi River in the St. Louis area (33) recommended a combination of effluent standards and stream standards. The report recommended that phenol concentrations in the stream be limited to a monthly average of 2 p.p.b. and a maximum of 5 p.p.b. and that the threshold odor number be limited to

a monthly average of 10 and a maximum of 30.

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NATIONAL REGISTER OF SANITARY ENGINEERING PERSONNEL

The Public Health Service, in cooperation with the National Science Foundation, recently distributed a questionnaire to all known sanitary engineers. The results of this questionnaire will be used in the development of a national register of sanitary engineers. This register will be part of the National Register of Scientific and Technical Personnel established and maintained since 1950 by the National Science Foundation. Inclusion of sanitary engineers in the register is being undertaken at the request of the Office of Defense Mobilization. Data on sanitary engineers will be kept current by the USPHS, probably on a biennial basis.

If you consider yourself eligible to qualify under the National Research Council definition of sanitary engineer (THIS JOURNAL, **27**, 5, 586; May, 1955) and have not received a questionnaire, contact the Chief Engineer, Division of Sanitary Engineering Services, PHS, Department of Health, Education and Welfare, Washington 25, D. C. The register will be only as successful as the returns of the sanitary engineers are complete.

Sewage Works

BUFFALO SLUDGE DISPOSAL FACILITIES *

By Frederick W. Crane, George F. Fynn, and Charles R. Velzy

Respectively, General Manager and Works Superintendent, Buffalo Sewer Authority, Buffalo, N. Y., and Partner, Nussbaumer, Clarke & Velzy, Inc., Consulting Engineers, New York, N. Y.

The Bird Island Sewage Treatment Plant of the Buffalo Sewer Authority (Figure 1) was completed and placed in operation in 1938. Providing primary sewage treatment, the facilities consist of a 570 m.g.d. main pumping station, coarse trash racks, fine bar screens, grit chambers, chlorination, sedimentation and sludge disposal by incineration. The population of Buffalo according to the 1950 census was 580,000. At present the city may be considered stabilized both in area and population. Some sewage is received from areas outside the city limits having a population of not more than 30,000. The present domestic sewage loading of the treatment plant is equal to the wastes from approximately 610,000 persons plus normally acceptable industrial and commercial wastes. The latter wastes have a B.O.D. population equivalent of 300,000. The 16-year average daily flow has been 142 million gal.

The four original 90-ft. diameter sludge storage tanks have a sidewall depth of 27.5 ft. and a 4 to 1 sloping conical bottom. Total storage capacity is 738,000 cu. ft., equivalent to approximately one cubic foot per capita based on a design population of 750,000. Raw sludge solids are obtained from four sedimentation tanks 160 ft. in diameter with a sidewater depth of 14.5 ft. Routine operation consists of intermittent withdrawals of settled sludge to obtain material having a 5 to 7 per cent dry solid content. During the years of treatment plant operation, the raw sludge averaged 6.1 per cent dry solids and contained 65.0 per cent volatile matter. The pH of the sludge averaged 6.5 and the ether soluble material ranged up to 20 per cent.

Suspended solids in the grit-free sewage have averaged 179 p.p.m., equivalent to 0.37 lb. per capita per day, for the 16 years of operation. This amounts to a total of 213,000 lb. per day for the present population. Thirty-three per cent of this load has been removed by the settling tanks. The original sludge storage-digestion tanks have been loaded at an average rate of 72,000 lb. of solids (dry weight) per day, which is equivalent to approximately 0.10 lb. per cubic foot per day.

In 1950, the Buffalo Sewer Authority determined to review its facilities in an attempt to overcome some of the operating problems that developed during the preceding 12 years of operation. Recent improvements in treatment were to be reviewed, taking cognizance of the increasing demand for further reduction in the pollution of the Niagara River. Where possible the degree of treatment afforded by the plant was to be improved. Consulting engineers were retained to

* Presented at 1955 Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Atlantic City, N. J.; Oct. 10–13, 1955.

FIGURE 1.—Aerial view of sludge digestion facilities at the Bird Island Sewage Treatment Plant, Buffalo, N. Y. Note new digesters under construction.

study the treatment facilities and prepare a program to accomplish these objectives. The studies revealed the desirability of providing additional settling tanks, pre-aeration facilities and additional sludge digestion tanks. Although elutriation had previously been considered, it had not been installed. The studies indicated an advantage in its use and it was included among the desirable additional features. Since meager and conflicting experience had been reported on pre-aeration, a pilot plant was built and operated to determine whether pre-aeration would be effective in treating Buffalo sewage. The results indicated insufficient improvement in treatment efficiency to warrant the cost.

Improvements undertaken to date consist of additional sludge digesters and elutriation tanks with a control building and appurtenances. These were the facilities most urgently needed since the handling of sludge through the original digesters presented increasingly difficult operational problems resulting from the accumulation of scum-forming material that almost completely filled the tanks with a dense, non-liquid mass.

Digestion Capacity

When the Buffalo sewage treatment plant was designed and constructed, the primary purpose of the sludge storage tanks was to provide storage prior to sludge filtration and incineration. The design capacity of 1.0 to 1.2 cu. ft. per capita appeared reasonable since complete digestion is not essential prior to incineration. The storage tanks were equipped with floating covers and gas production was an essential requisite. In the early years of operation, when most of the tank volume was available, reasonably good digestion was obtained.

Operating problems, however, developed early and have persisted through the years. The most troublesome has been the formation of a heavy layer of material at the top of the storage tanks. This layer on occasion has been more than 15 ft. thick and has contained as much as 20 to 30 per cent dry solids. The relatively solid consistency of the mass has made

it almost impossible to remove it from the tanks by the usual methods. This scum has become an inactive mass in which solids do not digest and the volume occupied is not available for normal sludge digestion. The activity in the tank becomes seriously inhibited, resulting in difficulties in handling the sludge and reducing the production of gas. Loss of gas production has increased operating costs by requiring the purchase of fuel oil to supplement the inadequate gas supply.

In 1950, a considerable amount of sludge contaminated liquid was found in the gas withdrawal line of one of the storage tanks. Investigation revealed that the entire center pipe-supporting structure was tilted out of position. A complete emptying of the tank contents was necessary to determine the condition of the structure base. This provided the first occasion for the complete dewatering of any of the sludge tanks since initial operation. On opposite sides of the tank were two piles of grit material totaling approximately 750 cu. yd. and composed of about 70 per cent sand and 21 per cent volatile matter. The need for a complete emptying of the other digestion tanks to restore them to maximum capacity was immediately apparent.

During the time this storage tank was being emptied and repaired, a program was instituted for modernization of the incinerator units. Consequently sludge disposal by incineration was discontinued for approximately 18 months while the required changes were made. At first it was possible to schedule sludge filtration for part of each day with disposal of wet cake on a dump area. However, this procedure had to be discontinued when the dump area was appropriated for other purposes. With sludge disposal facilities confined to incineration and limited land area precluding the disposal of sludge by lagooning, the inventories of the digestion-storage tanks increased until the total loading was about 100 per cent over the optimum. Failure of the tower structure in a second unit then made it mandatory to immediately schedule a second tank dewatering. An appreciable volume of this tank also was unavailable for digestion purposes due to the presence of large quantities of grit. Since the new digesters were put in operation, the third of the original sludge tanks has been dewatered and similar interior conditions were encountered.

Gas Production

The loss of digester capacity due to accumulations of grit, together with a solids overload, seriously affected gas production. Daily gas production has averaged 369,300 cu. ft. Production peaks were reached in 1941–42 and 1944–45 when the daily averages were 564,900 and 556,500 cu. ft. respectively. For the last three years, the daily averages have been 76,900, 52,-700 and 73,700 cu. ft. These last values reveal the extent of the stifling of digestion in the overloaded units and indicate the obvious reduced active capacity.

Supernatant

Another operating problem has been the return to the treatment plant influent of a supernatant from the sludge tanks carrying an excess of solid material. There have been extended periods when the material drawn as supernatant has been comparable to a light sludge. The dry solids content averaged 2.9 per cent. This, of course, has added to the load on the settling tanks, increased the chlorine demand of the sewage and in general has tended to cause deterioration of the plant effluent, especially during periods when the flow exceeded the design capacity which reduced the detention time.

Design

With the completion of preliminary studies, the consulting engineers pre-

pared plans and specifications for the required additional facilities. Construction was commenced in 1953 and it was possible to start operations in 1955.

Digesters

Present design requirements for separate sludge digestion tanks in a primary treatment plant, according to the New York State Department of Health standards, specify capacities of from 3 to 7 cu. ft. per capita. In order to approach these standards and alleviate the difficulties in the handling of sludge, the Authority selected as the first step in its improvement program the construction of four 100-ft. diameter digesters (Figure 2). These new digesters would provide an additional 942,000 cu. ft. of storage capacity and permit the establishment of a two-stage digestion procedure. It was also decided to construct and operate a sludge elutriation system.

The digester design was based on the amount of solids estimated to be obtained when settling capacity is increased in the future. Operating records show that approximately 38 per cent of the suspended solids (including grit) are removed. It was assumed that with future enlarged sedimentation capacity the removal of suspended solids would average 50 per cent. Had flocculation by pre-aeration proven practical, the removal would have been increased further. Past experience with the original sludge storage tanks was a guide to design and indicated where emphasis should be placed to overcome previous difficulties.

There are several factors which affect the accumulation of scum. The settling period is relatively short and the overflow rate high. As might be expected, the removal of solids has been low averaging 38 per cent. Under these conditions the proportion of the coarse material which contributes to scum formation has been high. Another factor which has aggravated scum formation is the inadequate capacity of the original digestion tanks. The tank area per unit quantity of solids is small and the depth of floating material builds up rapidly.

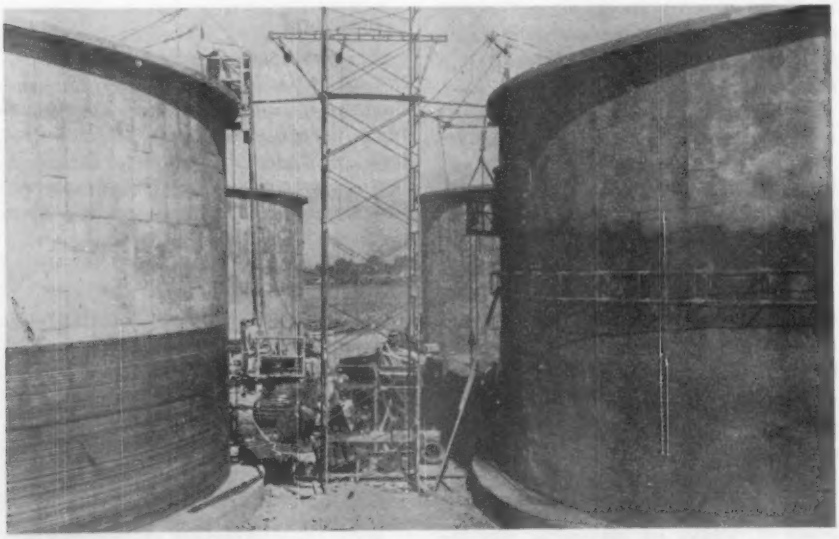


FIGURE 2.—New 100-ft. diameter digestion tanks showing stages in prestressed construction.

The objective in design of the original tanks was to provide storage for the solids from the primary settling tanks prior to disposal by filtration and incineration. When storage is provided, digestion takes place, whether desired or not, and treatment plant operation must be on that basis. The routine problems of digestion are present, and some of them are the more acute because of the small sludge capacity.

In designing the additional sludge digesters, therefore, it was assumed that the sludge tanks, old and new, would be digestion tanks rather than storage tanks. In accordance with recent developments, it was also determined that the design should provide for two-stage digestion, using the proposed 100-ft. diameter digesters as first-stage units and the existing 90-ft. diameter digesters for the second stage. In determining the volume required, consideration was given to the probability that more rapid digestion and more efficient and complete use of tank volume would be obtained now.

Some of the design features of the digesters relate to slope of cone, stirring facilities, cover and equipment to operate and control the digestion process. These features are an important part of the design because efficient digestion depends upon them to a large extent. Careful and adequate attention was given to efficiency and convenience of operation in the design of these new facilities.

The slope of the bottom cone and stirring facilities are features incorporated to keep active the maximum volume of the tank. The steep slope of the cone tends to minimize the accumulation of grit, whereas facilities for stirring including recirculation of sludge and gas, tend to break up scum and to keep the tank contents homogeneous.

The favorable experience with floating covers on the original digesters led to the decision to install floating covers on the new tanks.

Sludge Recirculation

For sludge recirculation, piping is arranged to draw digesting sludge from either of two points in the digester and discharge it at any of three other points. One of these three points of discharge is at the center of the tank near the top and the other two are at some distance removed from the center with the flow directed to induce a rotating movement to the entire sludge mass. Raw sludge is introduced with the recirculated sludge.

There are two centrifugal circulating pumps for each sludge digester. The 400-g.p.m. pump is used to mix the digesting sludge with raw sludge when the latter is pumped into the digester. The mixed sludge passes through the heater on the way to the tank. The larger pump, having a capacity of 1,000 g.p.m., is used when circulation is needed in excess of that obtained when pumping raw sludge. It discharges directly to the tank without passing through the heater. The higher rate of circulation is adequate to circulate the entire contents of the tank in approximately 30 hr.

Piping within the control building provides cross connections between the tanks so that digesting sludge may be drawn from any one of the new digester tanks and discharged into another tank by either of the circulating pumps.

Control Equipment

Digestion control equipment is housed principally in the control building located at the center of the group of four tanks. In the layout of this equipment, particular attention was given to convenience of operation and to making an agreeable place in which to work. Piping and equipment were arranged along the walls, leaving working space in the center. A court-like well was constructed from basement to top floor, providing daylight and ventilation to the basement and preventing the "shut-in" feeling

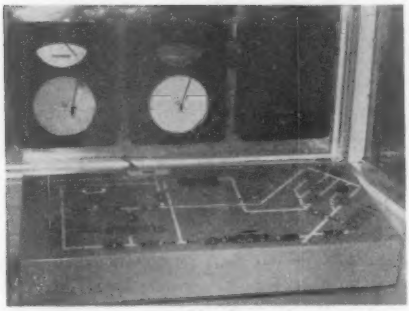


FIGURE 3.—Digester equipment control panel.

an operator may have when working in a crowded and closed area. The stairs and a small passenger elevator are located in this well.

On the top floor of the sludge control building there were installed two operating and observation stations. Meters, gages, remote control equipment and other appurtenances are mounted on graphic panels (Figure 3) with symbols for pipes, valves, pumps, sludge heaters and tanks. Suitable accessories are provided to start or stop sludge pumps and open or close pertinent valves in the basement. Meters indicate flow of sludge and gages show level of raw sludge in the receiving wells. This arrangement permits the operator to perform and observe all routine operations from one control center.

Elutriation

Elutriation was designed for two-stage, counter-flow operation utilizing rectangular tanks. Sludge enters through a measuring nozzle and water through a rate controller. Water is from the supply of plant water taken from the harbor. Sludge and water are mixed in a mixing box or chamber by means of a mechanical stirring device consisting of a small propeller on a motor driven shaft.

Structural Features

Several interesting structural features were incorporated into the design. The digester site was on a fill along the river bank with two of the tanks located partly on fresh fill of considerable depth. The walls of the tanks, the center of the floor cone and the pipe supports, therefore, were built on pile foundations. The floor was built as a paving slab extending from the wall footing to the heavy section at the center of the cone. Relief valves were installed in the floor slab to prevent upward pressure of ground water which might result in lifting of the slab.

The floor cone was constructed with a slope of 2.5 to 1.0, which is steeper than used in the original digesters. As mentioned previously, the design objective was to minimize the retention of grit on the slope and thus make more of the tank volume available for digesting sludge. Concrete was placed at this steep slope by using a dry mix and placing it in relatively small sections. For the tank walls, alternate designs were used; one of conventional reinforced concrete and the other of prestressed design. The prestressed design was accepted at the same cost to the owner as the conventional design.

Operation

With the completion of the expansion program a two-stage process for sludge digestion was instituted. During January, 1955, personnel were selected for the operation of the new digesters and given an instruction period to familiarize them with the equipment. By the end of the month, it was possible to start full operation. All raw sludge from the primary sedimentation units was pumped to the new digesters, constituting the primary stage.

Due to the condition and character of the sludge contained in the original storage-digestion tanks, it was inadvisable to transfer any appreciable amount of this material to the new digesters. For a period of several weeks, analyses indicated that there

was an acid or fermentation stage prevalent in all units. The carbon dioxide concentration of the gas analyzed from 60 to 70 per cent. Analyses of the sludge liquor indicated a pH range from 5.0 to 6.1 and the alkalinity varied from 1,300 to 1,700 p.p.m.

A deterrent to complete operation during this period was occasioned by the fact that 400 and 1,000 g.p.m. centrifugal sludge pumps were not available for use. Tank contents could be circulated only by utilizing the triplex plunger pumps which are used to transfer raw sludge from the receiving wells to the digesters and to pump primary sludge to the secondary units.

It was possible to maintain desirable temperature conditions within the digesters with four external heat exchangers of the counter-current flow type installed under this expansion program. Each unit has a rated capacity of 2,500,000 B.t.u. per hour. Raw sludge is pumped through the heater units before introduction into the digesters. Provision has also been made for circulating tank contents through the exchangers.

During May, 1955, the quality of gas from one digester was satisfactory for use in the incinerators and steam boiler. In the same period, the installation of the previously mentioned centrifugal sludge pumps was completed and they were placed in operation. By more effective circulation of digester contents, gas from the other three digesters was available toward the end of June.

Sludge tank inventory of the primary units during the first week in August, 1955, indicated an over-all load of slightly greater than 5,000,000 lb. of solids (dry weight basis). The present load is somewhat unevenly distributed among the four digesters due to periodic resting of individual tanks to permit improvement of pH conditions.

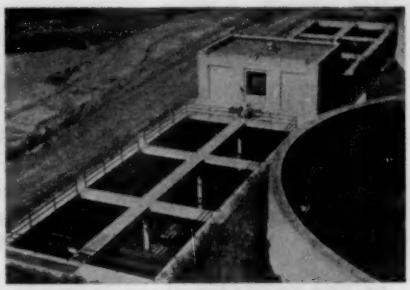


FIGURE 4.—Newly constructed elutriation tanks and control building.

A noteworthy result of the operation to date has been the increase in activity of the original sludge tanks now being used as second-stage digester units. Apparently the resting period provided while filling the primary digesters, together with some reduction in the over-all load and the maintenance of proper sludge temperature, has effected an increase in the digestion activity in these units. The secondary digesters are producing gas in excess of 300,000 cu. ft. per day, which is the highest average attained in the past four years. This production, in addition to the gas from the primary digesters, has permitted the discontinuance of oil as auxiliary fuel with accompanying economy.

Although a sludge elutriation system (Figure 4) has been included in the expansion program, it was not possible at the time of preparation of this paper to present any results.

Experience to date portends that when all phases of the present expansion are available for use, a more uniform type of sludge will be available for disposal and a better supernatant can be returned to the sedimentation tanks. This should materially improve plant efficiency.

SEWER RENTALS AND SEWER EXTENSION CHARGES IN MASSACHUSETTS *

By Clarence I. Sterling, Jr.

Chief Sanitary Engineer and Deputy Commissioner, Massachusetts Department of Public Health, Boston, Mass.

The Division of Sanitary Engineering of the Massachusetts Department of Public Health receives many inquiries each year in regard to financing sewer extensions, house connections and the maintenance and operation of systems. With rapid expansion of sewerage systems due to mass movement of the citizens to suburban areas, the problem of financing such extensions to serve newly developed areas has become acute. Although in the final analysis, the cost of sewerage services is borne by the citizens of the community, nevertheless, each community attempts to develop some formula of painless financing.

In Massachusetts the methods of financing sewerage systems are provided for in Chapter 83 of the General Laws. The cost of construction of sewerage systems is financed by serial bonds, the maximum period not to exceed 30 years. The General Laws provide, however, that the city shall be assessed not less than one-fourth nor more than two-thirds of the cost of laying out, constructing, maintaining and repairing common sewers. Many of the sewerage systems in Massachusetts have been in existence for a number of years so that the rates that have been established by the municipalities are frequently not realistic when compared with present day costs.

In an effort to secure information that would be helpful in guiding municipal officials in setting up realistic tariffs, a questionnaire was sent to all municipalities having public sewerage systems. The response to the questionnaire was excellent.

Financing Sewer Extensions

A study of the questionnaire showed that sewer extensions were financed in five different ways with some minor variations. Thirty-nine municipalities financed sewer extensions on the front foot basis; five municipalities financed on an area basis, usually with a maximum chargeable depth of 100 or 125 ft. for the property; 28 of the municipalities financed on a combination of the front foot method and the area method; 54 of the municipalities financed their extensions directly from general taxation with no specific charges to the persons directly benefited, while three municipalities assessed the actual cost of the construction directly on the persons benefited.

In the case of new subdivisions, 60 of the communities required that the sewers be installed and paid for by the developer, while 31 municipalities did not have such a requirement.

Section 21, Chapter 83 of the General Laws states that if land abuts upon more than one way, assessments for sewers based wholly or in part upon frontage shall be assessed upon the frontage upon one such way and upon so much of the frontage upon such other way as is not exempted by the board of sewer commissioners whose duty it is to make the assessment, and such board may exempt from assessment so much of the front-

* Presented at 1955 Annual Meeting, New England Sewage and Industrial Wastes Assn.; Auburndale, Mass.; Nov. 3, 1955.

age upon such other way as they consider just and equitable.

Seventy-nine of the communities submitting answers to the questionnaire gave their solution to the problem of corner lots. There were 15 different solutions, as follows:

1. Assessment based on the shortest frontage.
2. Assessment based on the longest frontage with a maximum of 100 ft.
3. Assessment based on one-half the frontage on each side.
4. Frontage assessment which exempts 100 ft. on the short side.
5. Frontage assessment which exempts 50 ft. on one side.
6. Frontage assessment which exempts 60 ft. on one side.
7. Frontage assessment which exempts 80 ft. on one side.
8. Frontage assessment which exempts 100 ft. on one side.
9. Frontage assessment which exempts 125 ft. on one side.
10. Frontage assessment based on the longest side or the side on which the sewer connection is located.
11. Frontage assessment based on the side with sewer connection.
12. Frontage assessment based on the longest frontage.
13. Assessment based on exemption of the shortest side.
14. No frontage exemption on either side.
15. Assessment based on exemption of 100 ft. on the longest side.

In regard to financing sewer connections, the law was recently changed so that now the property owner may take up to 10 years to finance both his house connection and the sewer charges at 4 per cent interest. The questionnaire showed that there were five methods of making charges for house connections. These were on the basis of (a) actual cost, (b) a fixed sum, (c) a unit foot cost, (d) general taxation or (e) paid for by the property owner.

Financing, Maintenance and Operation

The financing, maintaining and operation of sewerage systems are done by any one of three different methods or a combination of the methods. These methods are (a) general taxation, (b) fixed charge for each service connection or family, or (c) a charge based on water consumption. In the latter method the rate may be a percentage of the water bill or it may be a fixed rate per 100 cu. ft. as based on water meter readings. In the case of large installations the sewage flows are metered directly and the charges based accordingly.

Summary

A review of the data obtained from the 133 questionnaires returned would indicate that there is a need for a study to develop more uniform and realistic methods of financing sewer extensions, house connections and the cost of maintenance and operation of sewerage systems.

Editor's Note—Copies of the tabulated data obtained from the questionnaires can be obtained directly by writing to the author, Massachusetts Department of Health, 511 State House, Boston 33, Mass.

HYDRAULIC BEHAVIOR OF STORM-WATER INLETS

V. A Simplified Method of Determining Capacities of Single and Multiple Inlets

By Paul Bock, Wen-Hsiung Li, and John C. Geyer

Research Staff Assistant, Department of Sanitary Engineering; Associate Professor of Civil Engineering; and Professor of Sanitary Engineering, respectively; The Johns Hopkins University, Baltimore, Md.

The simplified method presented here has been developed to reduce the time required to determine the capacities of single and multiple inlets. Although the results obtained will not be quite as reliable as those calculated from the formulas given in the references (1)(2)(3)(4)(5)(6), the saving in time required for routine office design may well justify the slight sacrifice in accuracy.

Letter Symbols

The symbols used in this article are:

g = gravitational acceleration (ft. per sec. per sec.)

L = length of inlet (ft.)

L' = length to capture outside portion of flow (ft.)

L_0 = length to capture flow which crosses upstream side of grate (ft.)

q_s = carry-over flow over the grate (c.f.s.)

Q = discharge into inlet (c.f.s.)

Q_0 = gutter flow (c.f.s.)

s = street grade (ft. per hundred feet)

v = mean velocity of flow at upstream end of inlet opening (f.p.s.)

v_0 = mean velocity of gutter flow (f.p.s.)

w = width of grate (ft.)

W_i = width of intercepted flow (ft.)

W_0 = width of original gutter flow (ft.)

y = depth of flow at curb line at the upstream end of inlet opening (ft.)

y_0 = depth of gutter flow at curb line (ft.)

θ = angle between plane of depression and vertical

θ_0 = angle between plane of street and vertical

The simplified method is based on the assumption that the velocity throughout the cross-section of the gutter flow is uniform. It follows that the ratio of intercepted width of flow to total width of flow (W_i/W_0) geometrically determines the per cent capture (Q/Q_0). Another assumption is that there is no carry-over across the grate in a single inlet or across the downstream grate in a multiple inlet.

Figure 1 shows a multiple inlet consisting of two separated gutter inlets with curb openings. The upstream inlet is parallel to the gutter line; the downstream inlet is perpendicular to the gutter line. Flow lines representing the outside limits of various flow rates have been drawn. The construction of these flow lines is explained later. The triangle, ABC, represents the triangular gutter flow area for a flow of 12 c.f.s. The flow intercepted by the upstream grate is bounded by

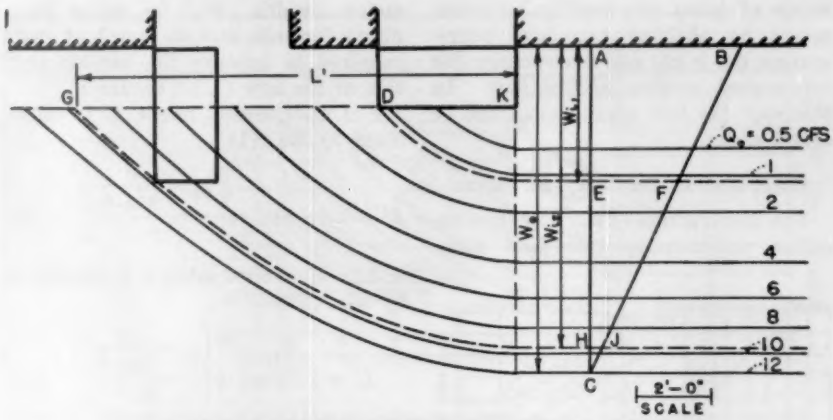


FIGURE 1.--Typical flow diagram for a multiple inlet.

the dotted flow line, DEF. The cross-sectional area of this intercepted flow is represented by the trapezoid, ABFE. Assuming uniform velocity the capture ratio, Q/Q_o, is equal to the areal ratio, ABFE/ABC. Thus, the capture ratio bears a constant relationship to the width-of-flow ratio (W_i/W_o) and can be easily picked from the curve shown in Figure 2. For the upstream grate alone (W_{i_1}/W_o) = 0.377. From Figure 2, $Q/Q_o = 61.2$ per cent. For the two inlets (W_{i_2}/W_o) =0.922 and $Q/Q_o = 99.1$ per cent. That is, the two inlets capture 11.3 c.f.s., 99.1 per cent of the 12 c.f.s. gutter flow.

Capacities for different arrange-

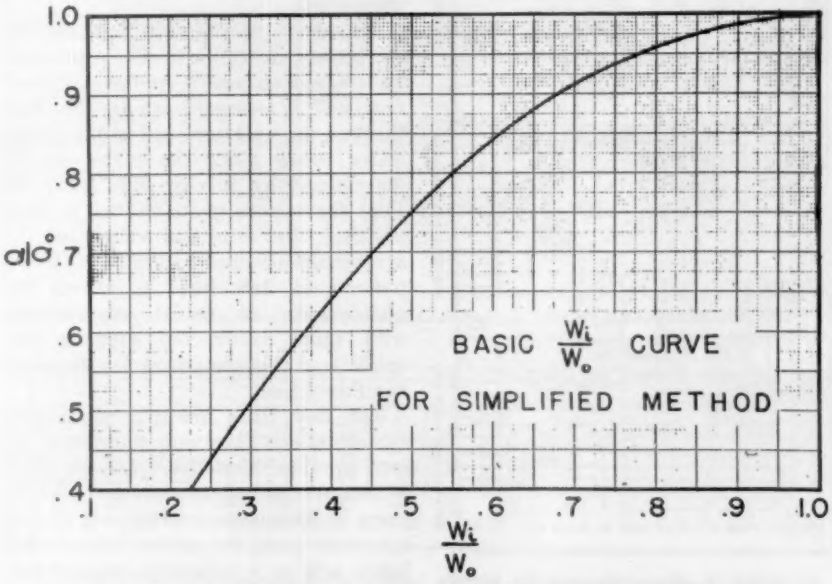


FIGURE 2.—Relationship of capture ratio to width-of-flow ratio.

ments of inlets can readily be determined by shifting templates representing the inlets and determining the intercepted portion of the flow. In this way, the best arrangement can be found easily.

Computation for Various Flows

The construction of the flow lines requires determining two flow parameters: width (W_0) by using Manning's formula, and the length of grate required to capture the outside portion of the flow (L') (Figure 1).

For undepressed inlets, L' is calculated by Eq. (1a).

$$L' = 1.2\, v_0 \tan.\theta_0 \left[\frac{y_0 - \frac{w}{\tan.\theta_0}}{g} \right]^{\frac{1}{2}} \quad (1a)$$

and for depressed inlets it is calculated by Eq. (1b).

$$L' = 1.2\, v \tan.\theta \left[\frac{y - \frac{w}{\tan.\theta}}{g} \right]^{\frac{1}{2}} \quad (1b)$$

For any given flow and street grade, W_0 is determined solely by the gutter geometry. The length, L', is determined by both gutter geometry and inlet dimensions such as width of grate and depression depth. The computation of W_0 for various flows can be greatly facilitated by use of nomographs or charts for solving flow in a triangular gutter. For depressed inlets, solution of equation (1b) for L' is facilitated by use of (E *vs.* y) curves (6).

The shape of the flow lines can be established as follows: The upstream ends are determined by the width of flow (W_0) measured along the line through the upstream end of the grate. Other points along the curve can be determined by solving Eqs. (1a) or (1b) for various grate widths, w, and plotting the resulting values of L' against the assumed values of w. Comparison of flow lines as shown by photographs of model experiments with those constructed suggests the validity of this procedure for drawing the flow lines.

The flow lines are also applicable for situations involving separated inlets, provided that the upstream inlet is not overtopped excessively. When there is little or no overtopping of the upstream grate, the gutter between the inlets acts as a collection channel for the part of the flow outside of the upstream grate. The part of the flow

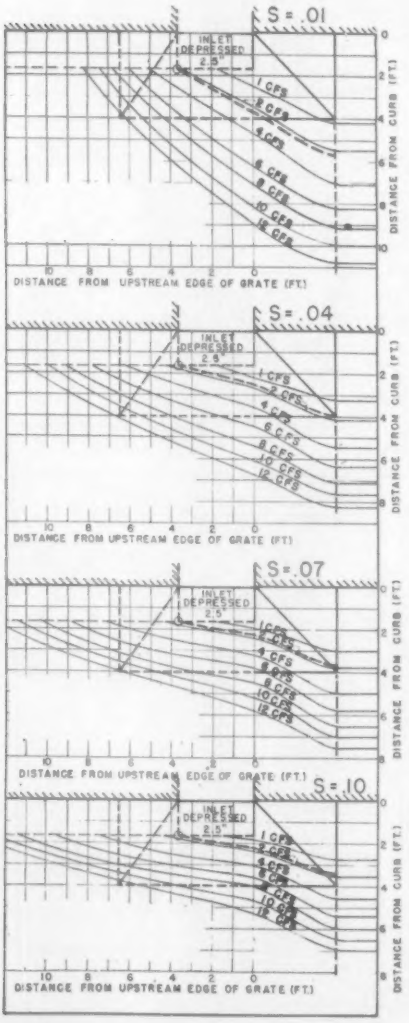


FIGURE 3.—Flow diagram for simplified method. Crown slope 1:18, $n = 0.013$. Depression depth = 2.5 in., width = 4 ft.

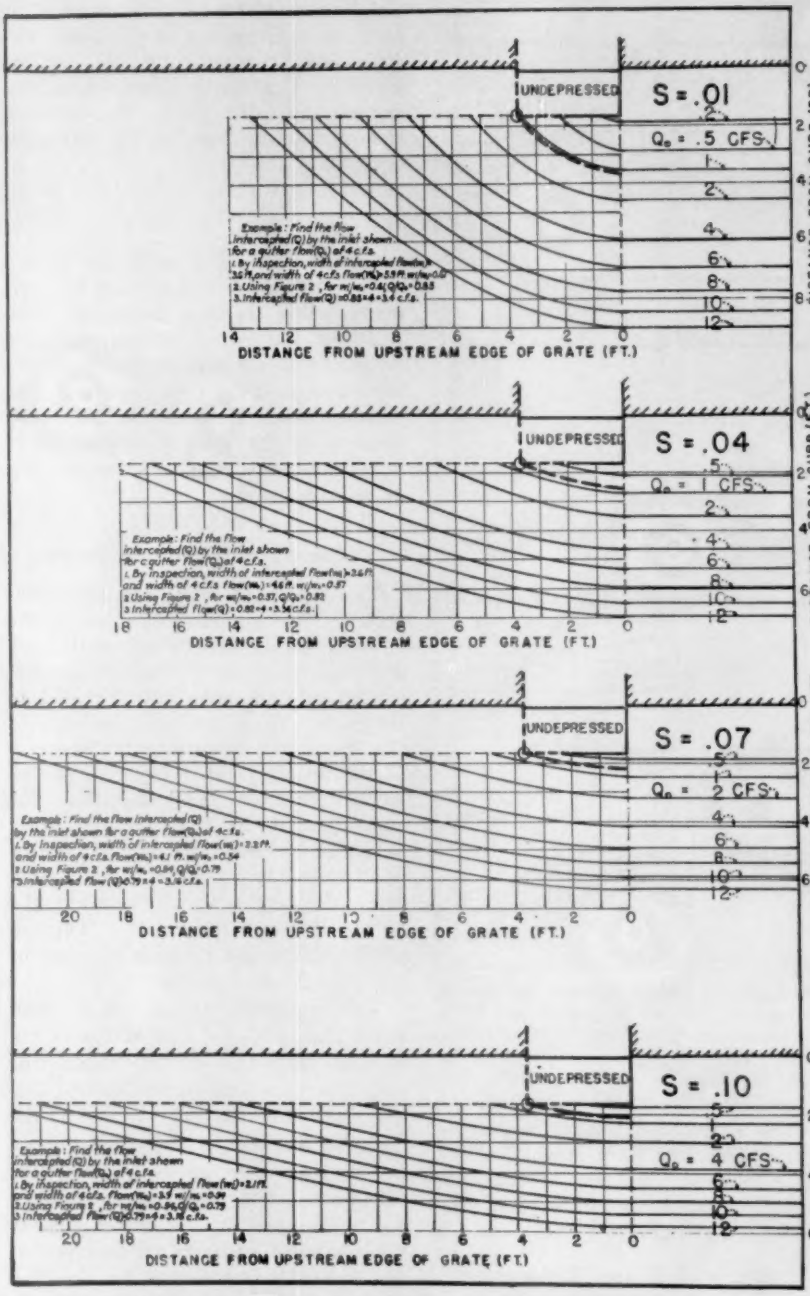

UNDEPRESSED
S = .01
Qo = .5 CFS
1
2
4
6
8
10
12
Example: Find the flow intercepted (Q) by the inlet shown for a gutter flow (Qo) of 4 c.f.s.
1. By inspection, width of intercepted flow (w) = 3.5 ft. and width of 4 c.f.s. flow (Wo) = 5.9 ft. w/Wo = 0.6
2. Using Figure 2, for w/Wo = 0.6, Q/Qo = 0.83
3. Intercepted flow (Q) = 0.83 × 4 = 3.4 c.f.s.
14 12 10 8 6 4 2 0
DISTANCE FROM UPSTREAM EDGE OF GRATE (FT.)
0 2 4 6 8 10
DISTANCE FROM CURB (FT.)
UNDEPRESSED
S = .04
Qo = 1 CFS
.5
2
4
6
8
10
12
Example: Find the flow intercepted (Q) by the inlet shown for a gutter flow (Qo) of 4 c.f.s.
1. By inspection, width of intercepted flow (w) = 3.6 ft. and width of 4 c.f.s. flow (Wo) = 4.6 ft. w/Wo = 0.87
2. Using Figure 2, for w/Wo = 0.87, Q/Qo = 0.82
3. Intercepted flow (Q) = 0.82 × 4 = 3.3 c.f.s.
18 16 14 12 10 8 6 4 2 0
DISTANCE FROM UPSTREAM EDGE OF GRATE (FT.)
0 2 4 6 8 10
DISTANCE FROM CURB (FT.)
UNDEPRESSED
S = .07
Qo = 2 CFS
.5
1
2
4
6
8
10
12
Example: Find the flow intercepted (Q) by the inlet shown for a gutter flow (Qo) of 4 c.f.s.
1. By inspection, width of intercepted flow (w) = 3.3 ft. and width of 4 c.f.s. flow (Wo) = 4.1 ft. w/Wo = 0.54
2. Using Figure 2, for w/Wo = 0.54, Q/Qo = 0.79
3. Intercepted flow (Q) = 0.79 × 4 = 3.16 c.f.s.
20 18 16 14 12 10 8 6 4 2 0
DISTANCE FROM UPSTREAM EDGE OF GRATE (FT.)
0 2 4 6 8 10
DISTANCE FROM CURB (FT.)
UNDEPRESSED
S = .10
Qo = 4 CFS
.5
1
2
4
6
8
10
12
Example: Find the flow intercepted (Q) by the inlet shown for a gutter flow (Qo) of 4 c.f.s.
1. By inspection, width of intercepted flow (w) = 2.1 ft. and width of 4 c.f.s. flow (Wo) = 3.9 ft. w/Wo = 0.54
2. Using Figure 2, for w/Wo = 0.54, Q/Qo = 0.79
3. Intercepted flow (Q) = 0.79 × 4 = 3.16 c.f.s.
20 18 16 14 12 10 8 6 4 2 0
DISTANCE FROM UPSTREAM EDGE OF GRATE (FT.)
0 2 4 6 8 10
DISTANCE FROM CURB (FT.)

FIGURE 4.—Flow diagram for simplified method. Crown slope 1:18, $n = 0.013$. Undepressed inlet.

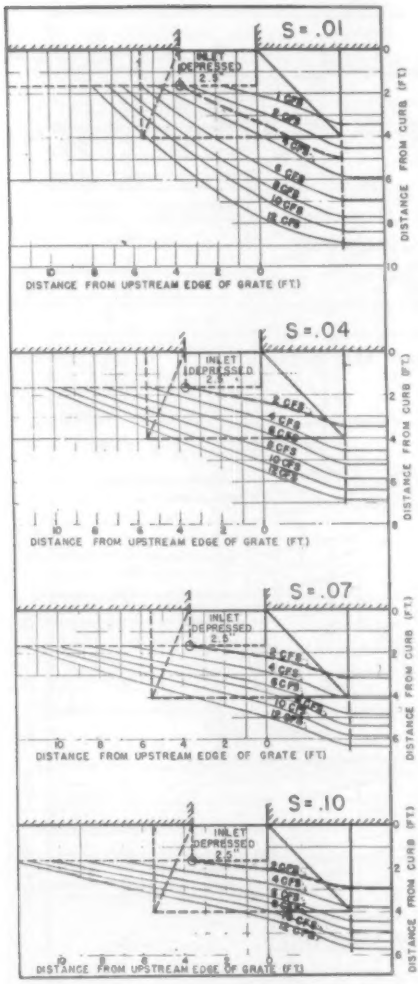


FIGURE 5.—Flow diagram for simplified method. Crown slope 1:24, $n = 0.013$. Depression depth = 2.5 in., width = 4 ft.

from the outside and any flow that overtops the upstream grate combine to form a gutter stream of increasing width. The flow lines outside of the gutter stream remain unchanged; within the gutter stream the flow may be considered parallel to the curb.

Width of Gutter Streams

The width of the gutter stream determines how the second inlet acts. The gutter stream is composed of a constant overtopping flow, q_3, and the side flow coming into the gutter stream. The latter increases in the downstream direction. To estimate the overtopping flow, use the following equation:

$$q_3 = Q_0 w / W_0 \left[2\left(1 - L^2/L_0^2\right) - w/W_0\right]$$

The flow coming into the gutter stream from the outside can be estimated using the flow diagrams. The width of the gutter stream can then be estimated for any section from the total flow past the given section. The location of the downstream inlet with respect to the gutter stream determines whether the inlets act separately or as a single unit.

Capacity of Separated Inlets

Two separated inlets can be considered as two independent inlets if the downstream inlet lies wholly within the gutter stream, since the flow to the second inlet is essentially parallel to the curb. To estimate the capacity of the inlets, first determine the capacity of the upstream inlet using the original gutter flow. Next determine the capacity of the downstream inlet, using as its gutter flow the original gutter flow minus the intake of the upstream inlet plus any flow which enters the gutter between the inlets. The capacity of the two inlets is the sum of the intakes of each inlet.

Two separated inlets can be considered as a single unit if the downstream inlet lies partly within the gutter stream and partly in the outside flow. For this case the flow to the downstream inlet is composed of two parts: the gutter stream and the outside flow. If the downstream inlet is not overtopped by the gutter stream, the combined capacity of the two inlets is the flow bounded by the flow line which intersects the outside corner of the downstream grate.

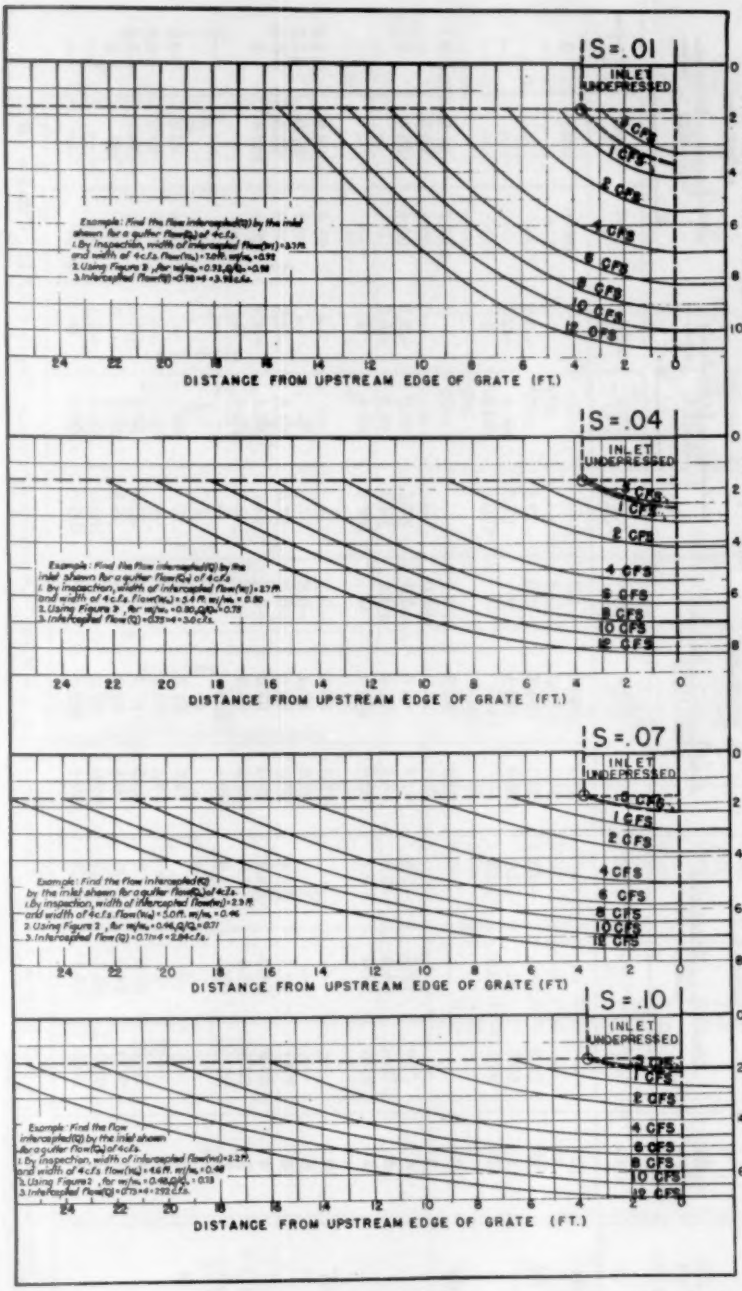


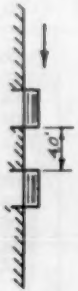
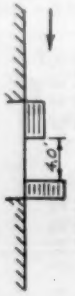
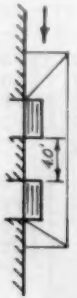
FIGURE 6.—Flow diagram for simplified method. Crown slope 1:24, $n = 0.013$. Undepressed inlet.

TABLE I.—Comparison of Capacities of Inlets* by Simplified Method and by Solution of Equations

Street Slope, s (ft./ft.)	Gutter Flow, Q_0 (c.f.s.)	1. Undepressed			2. Undepressed			3. Depressed			4. Depressed		
		Q/Q_0† (%)	Q/Q_0‡ (%)	Difference (%)	Q/Q_0† (%)	Q/Q_0‡ (%)	Difference (%)	Q/Q_0† (%)	Q/Q_0‡ (%)	Difference (%)	Q/Q_0† (%)	Q/Q_0‡ (%)	Difference (%)
.01	10	—	—	—	87.9	86.2	+1.7	—	—	—	100+	100+	0
	8	—	—	—	94.7	89.3	+5.4	—	—	—	—	—	—
	6	78.2	78.5	−0.3	98.1	94.5	−3.6	92.3	95.5	−3.2	—	—	—
	4	85.5	84.5	+1.0	100+	100+	0	97.5	100+	−2.5	—	—	—
	2	96.1	93.2	+2.9	—	—	—	100+	100+	0	—	—	—
.04	10	—	—	—	82.8	81.9	+0.9	—	—	—	97.7	97.8	−0.1
	8	—	—	—	86.9	84.9	+2.0	—	—	—	99.5	99.5	0
	6	72.0	79.8	−7.8	91.8	88.5	+3.3	89.7	93.0	−3.3	100+	100+	0
	4	78.6	84.0	−5.4	96.5	91.9	+4.6	94.3	99.3	−5.0	—	—	—
	2	91.6	92.0	−0.4	100+	100+	0	100+	100+	0	—	—	—
.07	10	—	—	—	77.3	80.5	−3.2	—	—	—	95.8	94.8	+1.0
	8	—	—	—	82.6	83.4	−0.8	—	—	—	98.3	97.0	+1.3
	6	72.1	80.5	−8.4	87.6	86.9	+0.7	87.0	91.5	−4.5	99.9	99.5	+0.4
	4	80.0	84.2	−4.2	94.2	92.0	+2.2	93.7	98.1	−4.4	100+	100+	0
	2	92.0	91.0	+1.0	99.9	98.0	+1.9	100+	100+	0	—	—	—
	1	99.4	97.5	+1.9	100+	100+	0	—	—	—	—	—	—
.10	10	—	—	—	74.6	81.8	−7.2	—	—	—	95.8	86.2	+9.6
	8	—	—	—	78.6	84.5	−5.9	—	—	—	98.0	92.6	+5.4
	6	73.2	80.5	−7.3	83.6	87.3	−3.7	89.6	89.0	+0.6	99.9	98.9	+1.0
	4	81.0	85.0	−4.0	90.5	89.9	+0.6	95.5	97.5	−2.0	100	100	0
	2	93.0	93.5	−0.5	99.0	97.0	+2.0	100+	99.6	+0.4	—	—	—
	1	99.6	98.3	+1.3	100+	100+	0	100+	100+	0	—	—	—

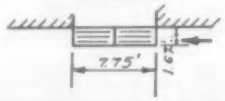
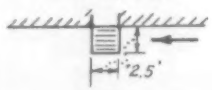
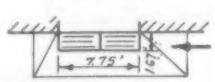
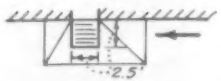
* Grate dimensions: $L = 3.67$ ft.; $w = 1.67$ ft. Crown slope 1:18; $n = 0.013$. Depression dimensions: Depth = 2.5 in.; Width = 4.0 ft.
† Q/Q_0 by simplified method.
‡ Q/Q by equations.

TABLE II.—Capacity of Multiple Inlets*

Street Slope, s (ft./ft.)	Gutter Flow, Q_0 (c.f.s.)	5 	6	7 	8 	9	10	11
		Capture Ratio, Q/Q_0 (%)						
.01	10	99.9	92.8	99.9	100+	100+	100+	100+
	8	100+	95.9	100+	100+	100+	100+	100+
	6	100+	98.8	100+	100+	100+	100+	100+
.04	10	94.9	94.0	99.5	100+	100+	100+	82.0
	8	99.6	99.4	100+	100+	100+	100+	86.3
	6	100+	100+	100+	100+	100+	100+	91.0
.07	10	89.3	94.3	98.9	100+	—	—	77.5
	8	96.6	99.5	100+	100+	—	—	82.0
	6	100+	100+	100+	100+	—	—	86.0
.10	10	93.8	96.5	99.5	100+	—	—	81.0
	8	82.5	98.5	100+	100+	—	—	84.8
	6	99.9	100+	100+	100+	—	—	89.6

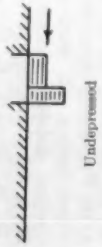
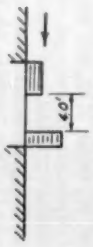
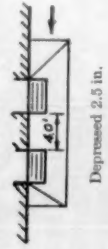
* Grate dimensions: $L = 3.67$ ft., $w = 1.67$ ft. Crown slope 1:18; $n = 0.013$.

TABLE III.—Comparison of Capacities of Inlets* by Simplified Method and by Solution of Equations

Street Slope, s (ft./ft.)	Gutter Flow, Q_o (c.f.s.)	12. Undepressed 			13. Undepressed 			14. Depressed 			15. Depressed 		
		Q/Q_o† (%)	Q/Q_o‡ (%)	Difference (%)	Q/Q_o† (%)	Q/Q_o‡ (%)	Difference (%)	Q/Q_o† (%)	Q/Q_o‡ (%)	Difference (%)	Q/Q_o† (%)	Q/Q_o‡ (%)	Difference (%)
.01	8	80.4	84.1	−3.7	—	—	—	100+	100+	0	—	—	—
	6	86.0	88.5	−2.5	70.5	77.0	−6.5	—	—	—	92.2	97.2	−5.0
	4	92.4	94.6	−2.2	78.0	81.2	−3.2	—	—	—	97.0	99.9	−2.9
	2	99.4	100+	−0.6	90.5	89.8	+0.7	—	—	—	100+	100+	0
	1	100+	100+	0	98.6	96.5	+2.1	—	—	—	—	—	—
.04	8	78.5	80.0	−1.5	—	—	—	98.8	98.5	+0.3	—	—	—
	6	84.0	82.8	+1.2	72.3	80.5	−8.2	100+	100+	0	95.2	97.0	−1.8
	4	91.0	88.3	+1.7	80.2	84.5	−4.3	—	—	—	99.0	99.5	−0.5
	2	98.9	96.9	+2.0	92.0	92.5	−0.5	—	—	—	100+	100+	0
	1	100+	100+	0	99.1	98.5	+0.6	—	—	—	—	—	—
.07	8	77.5	78.3	−0.8	—	—	—	96.5	96.0	+0.5	—	—	—
	6	83.4	81.6	+1.8	73.4	82.1	−8.7	99.0	98.5	+0.5	96.2	86.3	+9.9
	4	90.6	86.9	+3.7	80.5	86.8	−6.3	100+	100+	0	99.4	99.7	−0.3
	2	98.5	95.5	+3.0	82.6	94.2	−11.6	—	—	—	100+	100+	0
	1	100+	100+	0	99.4	99.0	+0.4	—	—	—	—	—	—
.10	8	75.5	79.0	−4.5	—	—	—	95.4	93.4	+2.0	—	—	—
	6	80.7	82.1	−1.5	76.1	83.5	−7.4	98.2	96.8	+1.4	95.7§	74.9	+20.8
	4	88.1	88.8	−0.7	84.0	88.0	−4.0	100+	100+	0	99.4§	86.3	+13.1
	2	97.3	96.3	+1.0	94.7	95.2	−0.5	—	—	—	100+§	92.1	+ 7.9
	1	100+	100+	0	100+	99.5	+0.5	—	—	—	—	—	—

* Crown slope 1:24; $n = 0.013$. Depression dimensions: Depth = 2.5 in.; Width = 4.0 ft.
† Q/Q_o by simplified method.
‡ Q/Q_o by equations.
§ Assumes no overtopping of grate.

TABLE IV.—Capacity of Multiple Inlets*

Street Slope, s (ft./ft.)	Gutter Flow, Q_0 (c.f.s.)	16	17 	18 	19 	20	21	22
		Capture Ratio, Q/Q_0 (%)						
.01	10	96.0	76.0	98.0	100+	100+	100+	100+
	8	99.9	80.4	99.9	100+	100+	100+	100+
	6	100+	85.7	100+	100+	100+	100+	100+
.04	10	89.8	65.5	94.0	100+	99.7	100+	92.0
	8	93.1	69.7	96.5	100+	100+	100+	94.7
	6	96.4	75.4	99.0	100+	100+	100+	98.0
.07	10	87.5	63.8	93.3	100+	100+	100+	79.0
	8	90.9	67.8	96.0	100+	100+	100+	83.0
	6	94.8	73.1	98.6	100+	100+	100+	88.5
.10	10	84.5	64.0	91.7	99.4	100+	100+	81.4
	8	87.6	67.9	94.5	100+	100+	100+	85.8
	6	92.5	73.2	97.6	100+	100+	100+	90.5

* Grate dimensions: $L = 3.67$ ft., $w = 1.67$ ft. Crown slope 1:24; $n = 0.013$.

Depressed and Undepressed Inlets

Figures 3, 4, 5 and 6 show a series of flow diagrams for depressed and undepressed inlets typical of the kind used in the Baltimore area. The curves have been constructed for a gutter section of cross slope 1:18 ($tan.\ \theta_0 = 18$) and a Manning's roughness of $n = 0.013$. The depression has a depth of 2.5 in. and a width of 4.0 ft.

Tables I and III compare the results given by the equations as presented in references (1)(2)(3)(4)(5) and (6), and by the simplified method. Good agreement is obtained for all reasonable design flows.

Tables II and IV present rating curve data for a series of closely spaced inlets determined by the simplified method. No comparison with equational solutions is attempted, since the equations are not applicable for such arrangements of inlets.

Arrangement 11 in Table II shows that the simplified method is also applicable to multiple inlets using a curb opening downstream. Width of intercepted flow, W_i, is approximated by extrapolating the flow lines to the curb.

Tables II and IV allow comparisons of various arrangements of multiple inlets using grates and gutters typical of the Baltimore area. Crown slope 1:18 and 1:24, depression depth 2.5 in., depression width 4.0 ft., and Manning's roughness $n = 0.013$ are used. Grate dimensions are: length = 3.67 ft.; width = 1.67 ft.

For undepressed grates, capacity is increased by separating inlets. However, the increase in capacity must be considered in relation to the increase in cost of building separate inlets. Placing the downstream grate perpendicular to the curb line increases capacity, especially at the steeper slopes, provided the downstream inlet is not overtopped.

For depressed grates, no material increase in capacity is obtained by separating the inlets a short distance for design flows up to 10 c.f.s. For most design conditions, contiguous grates having a total length of 7.75 ft. have adequate capacity for all grades. Placing the downstream grate perpendicular to the curb line does not significantly alter the total capacity. However, in using this arrangement, there is danger of the grates being overtopped under large flows on steep grades.

Acknowledgments

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A SIMPLE METHOD FOR ESTIMATING TOTAL PHOSPHATE IN SEWAGE

By John H. Howard

Research Chemist, Research and Development Laboratories, Cranston Print Works Company, Cranston, R. I.

Biological methods for treating industrial wastes which contain high concentrations of organic matter are attaining considerable importance. Two such methods are the activated sludge and the trickling filter processes. Both depend upon microorganisms which consume the organic matter. Optimum amounts of oxygen, nitrogen and phosphorus are required for the performance of this function with maximum efficiency. A simple method for estimating phosphorus content is therefore essential to evaluating the effectiveness of either process.

A search of the literature failed to disclose a simple, exact method described in any detail. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes* (1) gives a method for estimating orthophosphate in water by a colorimetric technique. This is a modification of the Deniges colorimetric procedure as improved by Truog and Meyer (2). *Official Methods of Analysis of the Association of Official Agricultural Chemists* (3) gives a method for estimating total phosphoric acid in fertilizers gravimetrically or volumetrically. The following method is a modification of the procedures cited.

Reagents

1. *Ammonium Molybdate Stock Solution:* Dissolve 25 g. of $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$ in 150 ml. water and add to 280 ml. concentrated H_2SO_4 diluted to 750 ml. with water; dilute to 1 l. For use, dilute one part of the stock solution with four parts of water. Make up this diluted solution fresh for each use.

2. *Stannous Chloride Stock Solution:* Add 25 g. of $SnCl_2$ to 1 l. of 1:9 HCl, filtering if necessary. For use, dilute one part of the stock solution with four parts of water. Make up this diluted solution fresh for each use.

3. *Potassium Phosphate Standard Solution:* Add 0.7164 g. of dry KH_2PO_4 to 800 ml. water and dilute to one l. Dilute 5 ml. of this solution to 500 ml. Each ml. will contain 5 μg. of $PO_4^{=}$.

4. *Concentrated Sulfuric Acid.*

5. *Concentrated Ammonium Hydroxide.*

6. *Dilute Nitric Acid:* Dilute concentrated HNO_3 with three volumes of water.

Procedure

Duplicate determinations are made for each sample. Place 10-ml. aliquots of sample in 30-ml. microkjeldahl flasks. Add 3 ml. concentrated H_2SO_4 and four or five glass beads. Heat on a microkjeldahl digestion rack for 2 hr. after the excess water has boiled away. (No difficulty will be encountered with bumping when boiling begins if the flask is continuously turned from the time the heat is first applied. After the contents of the flask begin to boil, the turning is no longer necessary.) Remove flasks and cool. Transfer contents of flasks to 125-ml. Erlenmeyer flasks, using four 4-ml. aliquots of water in the transfer. Af-

ter cooling, neutralize until just alkaline to litmus paper using concentrated NH_4OH (about 10 ml. will be required). Then make slightly acid with dilute HNO_3. Cool and dilute to 50 ml.

Place 1-, 3- and 5-ml. aliquots of each unknown in 20 × 150 mm. test tubes. Adjust volumes to 10 ml. In five other test tubes, place aliquots of the KH_2PO_4 standard solution to cover the range from 5 to 25 μg. Adjust the volumes to 10 ml. To each test tube add 2 ml. of ammonium molybdate solution and mix. Add 0.25 ml. of $SnCl_2$ solution and mix. Visually compare the unknowns against the standards at the end of 5 min.

Report in parts per million of $PO_4^=$ (micrograms per 5 ml. of digested and diluted sample.)

Discussion

Pyrophosphates, metaphosphates and orthophosphates all report quantitatively as orthophosphate. The optimum range for the standard phosphate solution is 5 to 25 μg. in 5 μg. increments, giving five tubes in all. It is possible to shorten this range to 3 to 12 μg. or 4 to 20 μg. if so desired. Of course the number of standard tubes is still restricted to five. Definition is quite sharp in any case.

As outlined the method is rapid and does not require photometric comparison; visual comparison suffices. The colors have been found to be sufficiently stable for precise results 24 hr. after development, providing the standards and unknowns were prepared at the same time.

The hydrolysis method is superior to any cited in the literature. The need for any acid other than sulfuric acid during digestion is eliminated.

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JOURNAL BACK NUMBERS

Response to previous appeals for Journal back numbers has been most gratifying and is sincerely appreciated. The January, 1955 issue of SEWAGE AND INDUSTRIAL WASTES, however, is still in short supply and back numbers are needed. Reimbursement is at the rate of $0.50 per copy plus postage.

Back numbers of the Journal also are available for purchase by members who desire to complete their libraries. Although a complete selection of all back numbers is not available and a few copies are limited, most of them are available. Orders for scarce numbers are filled if and when copies are obtained.

Occasionally a complete Journal file becomes available through the death of a Federation member. The Federation Secretary would be pleased at any time to help prospective Journal buyers and sellers make contact.

Industrial Wastes

PROBLEMS OF RADIOACTIVE WASTE DISPOSAL *

By Conrad P. Straub

Senior Sanitary Engineer, USPHS, assigned to Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

During the last 13 years the capital investment in atomic energy plant facilities has been estimated to be $6.6-billion before depreciation reserves. Until recently, the entire program has been under direct government control. However, since the passage of the Atomic Energy Act of 1954, 25 industrial participation groups representing 81 individual firms have made power demonstration reactor studies. In addition, major construction work is in progress at the Shippingport, Pa., site of the first civilian nuclear power plant in the United States. This is a 60,000 kw. version of the pressurized water reactor.

Any industrial operation will result in the production of waste products. In this, the atomic energy industry is no exception, and the wastes must be removed from waste streams or their concentrations must be reduced to an innocuous level prior to their release into the environment. These wastes are of particular concern because they are radioactive, and even at low concentrations, the radiations emitted are damaging to living tissue. Maximum permissible concentrations for many of the radioisotopes of interest in the body and in water and air have been reported (1).

The problem of radioactive waste disposal may be considered in three parts: (a) control of the quantities released; (b) knowledge of the behavior of individual radioisotopes between the point of release and entrance into the human body; and (c) knowledge of the behavior of individual radioisotopes in the human body. The first part, that of the control of the quantities released, is primarily a problem of chemical engineering, the specifications of which depend upon answers to the other two. Part two involves such phenomena as dilution of the radioisotopes after release, possible seepage of the radioactive materials into the water table or subterranean streams, and concentration of chemical elements by physical processes in plant and animal life. The third part includes effects of the various radiations on body tissues, and body uptake, distribution and excretion. Obviously, the solution of these problems cuts across many disciplines.

In this presentation, problems encountered in three types of operations or facilities will be discussed briefly and will include those associated with (a) nuclear power reactors and separation plants, (b) the disposal of radioisotopes following use in research, medicine, or industry and (c) a nuclear power reactor such as the one under construction at Shippingport, Pa.

Sources of Wastes

There are several sources of radioactive wastes: (a) nuclear reactors and

* Presented at 1955 Annual Meeting, Florida Sewage and Industrial Wastes Assn.; Orlando, Fla.; Oct. 6–9, 1955.

TABLE I.—Radioactive Liquid Wastes

System	Year				
	1950	1951	1952	1953	1954
Hot chemical waste system:					
Vol. received (1,000 gal.)	2,229	2,294[1]	2,192	2,287	1,669[2]
Vol. evaporated (1,000 gal.)	2,224	2,212	2,102	2,042	711
Vol. to waste pit (1,000 gal.)	0	123	43	227	997[2]
Radioactivity transferred (curies)	0	390	953	7,716	7,224
Radioactivity (curies/gal.)	0	3.17×10^{-3}	2.22×10^{-3}	3.4×10^{-3}	7.25×10^{-3}
Process waste system:					
Total vol. discharged to White Oak Creek (1,000 gal.)	226,350	297,590	268,180	239,356	164,290
Radioactivity discharged to White Oak Creek (curies)	187	172	498	429	254
Radioactivity (curies/gal.)	8.27×10^{-7}	5.8×10^{-7}	1.86×10^{-6}	1.79×10^{-6}	1.55×10^{-6}
Radioactivity (μc./ml.)	2.19×10^{-4}	1.54×10^{-4}	4.91×10^{-4}	4.73×10^{-4}	4.1×10^{-4}
Dilution required to reduce activity to 10^{-7} μc./ml.	2.19×10^{3}	1.54×10^{3}	4.91×10^{3}	4.73×10^{3}	4.1×10^{3}

[1] Includes 94,000 gal. of metal waste supernatant transferred directly by truck from metal waste tanks to waste pit.

[2] Includes 87,000 gal. of concentrated non-radioactive chemical wastes hauled by truck directly from operating buildings to waste pit.

separation plants, (b) radioisotopes used in research, medicine and industry, (c) nuclear bomb debris (fallout), and (d) power reactors.

Nuclear Reactors and Separation Plants

Perhaps the largest single source of radioactive liquid wastes in terms of volume is that from cooling the reactors as at Hanford, Wash., where treated Columbia River water is used. In passing through the reactor, enough radioactivity is induced in the water to make direct return to the Columbia River inadvisable and the cooling water passes through detention or delay tanks to permit decay of the short-lived radioisotopes. In the design of these basins, it is important that the theoretical and the actual detention times be as nearly equal as possible to avoid the discharge of short-lived radioisotopes. Warming of the receiving stream by the large volumes of cooling water should also be avoided. Where this is a problem, it may be advisable to cool the waste before discharge or to use a recirculating cooling-water system with detention tanks and cooling towers. If the radioactivity in the recirculating water becomes too great, removal of some of the objectionable radionuclides in ion exchange columns may be feasible.

Where a reactor is air cooled as at Oak Ridge National Laboratory, the cooling air is discharged through high efficiency filters and then through stacks before dilution with the atmosphere.

At Oak Ridge National Laboratory the liquid wastes are of three types:

1. Metal wastes, which contain dissolved compounds of uranium and which are held for recovery of the uranium.

2. Radiochemical wastes composed of highly radioactive fission products and various chemical by-products from the production and developmental processes in the laboratory.

3. Process wastes composed largely of cooling water and non-radioactive by-products. In Table I, the volumes of radiochemical (hot chemical wastes)

and process wastes handled are summarized as are data pertaining to the activity of the various waste streams. The concentration of activity in the two wastes differs by a factor of 10,000 and a dilution of 1,500 to 5,000 is required to reduce the concentration of the wastes discharged through the White Oak Creek system to 10^{-7} μc. per milliliter, the maximum permissible concentration for an unknown mixture of radioisotopes.

Some of the hot chemical wastes, those formerly concentrated by evaporation, are now pumped through a pipe line to surface pits located in the weathered Conasauga shale formations. These pits have a volumetric capacity of 180,000 and 1,000,000 gal., respectively. The first pit, which was put in on an experimental basis is completely covered with a wooden roof. The later pits, all of 1,000,000 gal. capacity, were covered over with a wire mesh screen. The reason for the cover in the first pit was to keep out rainfall and to prevent waterfowl from having access to the pit contents. In the case of the larger pits which were covered with screening, the purpose was to keep out waterfowl and other animals native to the area. To date, the three pits in use have received approximately 3,000,000 gal. of waste containing 35,275 curies of radioactivity. Other pertinent characteristics pertaining to these pits and their operation are given in Table II. The wastes added to pits Nos. 1 and 2 were highly alkaline (pH 12.5) evaporator concentrates, with a radioactivity of about 1/30 curies per gallon, principally as cesium and ruthenium (60 per cent Cs^{137}-Ba^{137} and 40 per cent Ru^{106}-Rh^{106}). The wastes added to pit No. 3 are less alkaline (pH about 10

TABLE II.—Waste Pit Characteristics [1]

Characteristic	Waste Pit Number		
	1	2[2]	3
Design capacity (gal.)	180,000	1,000,000	1,000,000
Pit dimensions (ft.):			
Length	100	210	210
Width	20	100	100
Depth	15	15	15
Period of use	Aug. 1, 1951 to Oct. 5, 1951	June 20, 1952 to Oct. 31, 1955	Jan. 24, 1955 to Oct. 31, 1955
Raw waste added (gal.)	123,000	1,331,760	1,434,600
Waste from pit No. 3 (gal.)	—	398,200[3]	—
Total waste volume (gal.)	123,000	1,729,960	1,036,400
Beta activity added (curies)	389	15,975	18,911
Beta activity taken from pit No. 3 (curies)	—	3,449[3]	—
Total beta activity (curies)	389	19,424	15,462
Radioisotopes present (per cent of total):			
$Cs^{137}-Ba^{137}$	60	60[3]	77
$Ru^{106}-Rh^{106}$	40	40[3]	12
$Sr^{90}-Y^{90}$	—	—	11
pH of waste added	12.5	12.5	10–11
Construction cost ($/m.g.)	14,500.00	14,500.00	14,500.00
Cost ($/gal. of waste capacity)	0.0145	0.0145	0.0145
Cost ($/gal. of waste discharge)	0.0212	<0.0084[4]	<0.0140

[1] Data as of Oct. 31, 1955.

[2] Liquid decanted from pit No. 3 and added to pit No. 2 after Jan. 24, 1955.

[3] Volume of waste and radioactivity decanted from pit No. 3 and added to pit No. 2. Radioactivity estimated from radioactivity added just before decanting.

[4] Based on total gallons of waste volume in pit.

to 11), are more dilute by a factor of 10 to 15, and contain measurable amounts of strontium in addition to the cesium and ruthenium (about 77 per cent cesium, 12 per cent ruthenium, and 11 per cent strontium). The waste added to pits Nos. 1 and 2 averaged 30 to 35 per cent total solids concentration and the principal stable constituents were Na^+, NH_4^+, and No_3^-.

Sampling and radio-logging wells have been provided for the purpose of monitoring ground water flow, and have shown that radioactive ruthenium and stable NO_3^- pass through the Conasauga shale formations. Six weeks after the introduction of the wastes into pit No. 2, ruthenium and nitrates were found in a sampling well 85 ft. distant. No evidence of radioactive cesium or any other radioactive cations in any of the wells has been observed in the three years of operation. Breakthrough of radioactive ruthenium and stable nitrate to a surface stream 500 ft. distant from the pit took place after two years of operation. The underground movement of the wastes corresponded with geologic and hydrologic findings of ground water flow in the disposal area. Because of its public health implications, the movement of stable NO_3^- through the soil is of considerable interest. Public health agencies have assigned a maximum allowable limit of 10 mg. per liter nitrate nitrogen to ground water supplies. The possible contamination of ground water aquifers with high nitrate waste from atomic energy installations should be avoided to prevent the possible development of methemoglobinemia in infants.

Isotope Usage

Radioisotopes have found wide usage in research, medicine and industry, and this usage is indicated by the data given in Table III which lists the number of shipments made and the number of curies shipped annually. It will be seen that the growth or development of this phase of the program has been extremely rapid until now more than 1,000 shipments are made monthly. Not only has the number of shipments increased, but the variety of isotopes and the amount of radioactivity shipped has also increased.

TABLE III.—Number of Isotope Shipments Made and Number of Curies Shipped (Oak Ridge National Laboratory)

Year	Total	Number of Shipments Made			Curies Shipped
		Non-Project	Project	Foreign	
1946[1]	279				
1947	1,933				
1948	3,543	2,633	578	332	86
1949	5,597	4,334	923	340	229
1950	8,075	6,282	1,574	219	825
1951	9,491	7,660	1,653	178	1,053
1952	10,691	9,318	1,129	244	3,080
1953	12,036	10,668	1,011	357	6,544
1954	12,670	11,395	1,026	249	23,088

[1] August through December.

In general, small amounts (microcurie and millicurie quantities) of single radioisotopes are used in tracer experiments, and the waste volumes which result are small and the concentration of radioactivity is low. Larger quantities, both in volume and radioactivity, may be discharged from hospitals where radioisotopes are used as therapeutic agents.

Increased use of these radioisotopes has resulted in the discharge of these materials to the environment. Guides have been prepared by various groups outlining the practices to be followed in the disposal of specific radioactive materials. These have been listed and the various recommendations pertaining to the discharge of iodine have been compared (2). There appears to be some confusion between the recommendations in the National Bureau of Standards Handbook 52 for this radioisotope and those found in some of the other guides (3)(4). Methods of calculating the hazard and permis-

sible levels of discharge have been discussed in other publications (5)(6).

Since the quantities of radioactivity involved are generally small, the simplest method of disposal is into a sewer system. A 1954 report showed that almost 41 per cent of 1,027 users of radioactive materials surveyed disposed of their radioactive wastes by dilution and discharge to sewers (7). Another method of disposal that has been suggested includes dilution with the stable element before discharge into the sewer. Although entirely satisfactory for some radioisotopes, care should be taken in other cases to avoid the creation of a chemical toxicity problem.

Nuclear Power Reactors

Nuclear power reactors have the greatest potential as a source of large amounts of radioactive waste. Provision of satisfactory methods for the handling and disposal of these high-level radioactive wastes (up to several hundred curies per gallon), which will result from the processing of fuel elements taken from nuclear power reactors, is of paramount importance if rapid development of this industry is to become a reality. It has been estimated (8) that by 1965 there will have been constructed some 5,000,000 kw. of nuclear power capability. By 1970, this will be increased to 27,000,000 kw., by 1975 to 83,000,000 kw., and by 1980 to 175,000,000 kw. Lieberman (8) reports as follows:

"Now when 1 g. of uranium is fissioned, 24,000 kwhr. (1 megawatt day) as heat energy is produced and about 1 g. of fission products is formed. One year after removal from a continuously operating reactor this 1 g. of fission product would be equivalent to about 1 w. of heat power. Using these 1965 values; 5,000 electric megawatts $\times$ 365/0.30 = 6.1 $\times$ 10^6 heat megawatt days per year.

"That is, from the nuclear power industry in 1965 we would expect 6.1 $\times$ 10^6 g. of fission products which at one year of age would have a heat power level of 6.1 $\times$ 10^6 w. Since 1 w. is equivalent to 500 curies, we arrive at a total quantity of radioactivity in 1965 of 3 $\times$ 10^9 curies. By 1980 this figure would increase to 1.05 $\times$ 10^{11} curies per year. This latter amount for comparison purposes is roughly twice the quantity of all the radioactivity in the oceans of the earth. One can calculate, using the figures previously given, and the 5.3 per cent fission yield for Sr^{90}, that for the 1980 rate of fission-product production it would require something like 2 $\times$ 10^{18} gal. of water to dilute the Sr^{90} to safe drinking levels." *

Several schemes have been suggested for the disposal of these highly radioactive wastes including ground disposal into deep wells, salt domes or salt strata, hydrologic basins or troughs, and coastal formations on the salt-water side of the interface between the salt water and the fresh water, as well as ocean disposal. However, because of a general lack of quantitative data or pertinent oceanographic factors, and the high costs and complex technical problems involved in preparing, handling and transporting high-level wastes to a suitable point of disposal, the possibilities of ocean disposal are not as good at present as those envisioned for land disposal.

Another approach provides for the fixation of the radioactivity on montmorillonite which is then heated to about 800° C. (9). It is reported that leaching is minimized by this procedure. The Oak Ridge National Laboratory is investigating the possibility of utilizing the waste heat from radioactive decay for fusing and fixing the radioactivity in local clay-flux mixtures.

Because of the high cost of tank storage facilities some consideration

* Subsequent calculations show that approximately 1 $\times$ 10^{18} gal. of water would be required rather than the 2 $\times$ 10^{18} gal. reported by Lieberman (8).

has also been given to the use of lined surface pits for the storage of these high-level wastes. Tank costs range from $0.30 to $2.00 per gallon of tank volume provided, and very little is known about the expected life of such facilities whereas surface pits, as built at Oak Ridge cost about $0.015 per gallon of capacity. The high temperatures expected during decay preclude the use of asphalt liner materials, unless provision is made for cooling the waste. Should a break occur in the liner or if the radioactive materials are placed directly in the ground, the reactions between the waste solution and the surrounding soil must be fully understood and appreciated, and these high-level wastes should not come in contact with potable ground water supplies. The movement of specific ions through the soil is important as this indicates the extent of contamination that may be expected.

It may be possible to separate the more hazardous radionuclides such as those of strontium, zirconium, niobium, yttrium, cesium and ruthenium from the bulk of the waste solution and provide storage facilities for these highly concentrated radioactive materials. Various chemical precipitation processes for separating the hazardous radioisotopes have been tried and showed some success (10). Solvent extraction processes and ion exchange procedures are under evaluation at present.

Shippingport Nuclear Power Facilities

As a specific example of the type of wastes that can be expected from a nuclear power reactor, the Shippingport facilities for waste handling and disposal are described (11). The reactor consists of a pressurized light-water cooled and moderated heterogeneous thermal-type reactor employing a combination of highly enriched and natural uranium fuel assemblies. The plant does not include any facilities for processing the spent fuel elements, and presumably these will be shipped to one of the national laboratories equipped with fuel element processing facilities. Therefore, radioactive wastes produced at this site and which must be disposed of will include only those incident to the operation of the reactor itself, and will not be of high concentration.

The primary waste sources and quantities are:

Waste	Flow (g.p.m.)	Radiation*
Miscellaneous liquid waste	50 to 400	1×10^6
Primary coolant, decontamination solution and flush water	50 to 75	5×10^6
Low-level laboratory and laundry waste	50	1.3
Condenser cooling water	68,000†	—

* Disintegrations per second per cubic centimeter.

† Minimum.

The waste disposal system is described as follows (11):

"The activity in the ion exchange resin from the purification system and in the decontamination fluids and primary system effluent will be too high to permit dumping into the river. The volumes involved make packaging and subsequent disposal at sea infeasible. The waste disposal system now being developed will consist of two-stage evaporation, to reduce bulk, and subsequent underground storage of high activity evaporator bottoms at the site. Spent resin from the demineralizers will be transferred by flushing, in the form of a slurry, directly to underground storage. Provision for collection and storage of radioactive gases is being made. Dilution and discharge through a vent stack will be used when meterological conditions permit. The evaporator feed will be from 9,000 to 21,000 cu. ft. per month depending primarily on decontamination proced-

ure. Evaporator vapor will be condensed and then diluted with condenser cooling water before release to the river. The permissible activity released to the river is being taken at 10 per cent of the standard tolerance. A study is underway to determine the most economical method of disposing of combustible radioactive waste. The methods being considered are an incinerator at the site, or baling and shipping for disposal at sea. High and low activity laboratory wastes will be separated at the source and processed through the evaporator or diluted and dumped as dictated by the activity."

Maximum Permissible Concentration Values

In dealing with and handling radioisotopes, the ideal objective is to retain absolute control of all radioactive waste materials as near their source of production as possible. Since this is generally impossible, the practical goal is that of preventing damage to human tissues, and in some instances of preventing economic waste. This goal may be reached by the judicious application of the criterion that external and internal dosages to plant operations personnel shall not exceed 0.3 rem per week, and its corollary that the concentrations of radioactive materials in air or water shall not exceed the published maximum permissible concentration (M.P.C.) values. In the case of long continued exposure and/or release of contaminants beyond the operations area of large installations, it may be desirable to use one-tenth of the values cited above. However, before this hazard can be estimated the composition of waste in terms of the radionuclides present, must be defined unless one wishes to apply the maximum level of 10^{-7} μc. per milliliter for mixtures of radioisotopes. For this, a knowledge of radiochemistry is necessary.

The identification of the radioactive components present is not too difficult if the number of radionuclides present is small and the concentration, in terms of radioactivity, is high. In the case of low concentrations of radioactivity, such as can be expected in some surface streams at the present time and which are at or near the M.P.C. levels, identification is not simple and becomes increasingly difficult as the number of radionuclides in the mixture increases. Another difficulty stems from the fact that radiochemical procedures for identifying the radionuclides present at these low levels are generally not available. Thus far procedures for strontium and barium have been published (12), and those for the other isotopes of interest (cesium, zirconium, niobium, cerium, yttrium, iodine and ruthenium) will be released shortly. By a process of elimination, *i.e.*, by showing that these more critical radionuclides are not present, the quantity of radioactive materials being discharged may be increased by a factor of 100 or more over the presently accepted M.P.C. value of 10^{-7} μc. per milliliter for mixed radioisotopes in water.

With these analytical procedures the scientist will be in a better position to follow the movement of radioactive materials downstream from their point of discharge and to observe the effect of natural agents on their removal. A better understanding of what takes place in the sewer, the sewage treatment plant, or the stream will be of considerable value in defining what may be discharged and at what concentration.

Summary

Two principles are employed in radioactive waste disposal, dilution and release or concentration and storage. In the case of the highly radioactive wastes dilution is not feasible and storage must be considered. Because of the high cost of such storage, reduction in bulk is essential.

Treatment of these wastes differs from the treatment of other waste materials. All that can be done is to transfer the radioactivity from one phase to another, as from the liquid to the solid. Only time will render the wastes innocuous and the time necessary for this to take place varies with the half-life of the material. Strontium is of major concern because it is deposited in the bone structure of man where it remains radioactive for many years. It has a long physical half-life (about 20 years) and a slow rate of elimination from the body (a long biological half-life of 10.7 years), thus exposing bone tissues over an extended period of time.

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America grows where water flows.

Stream Pollution

BACTERIOLOGICAL STANDARDS FOR BATHING WATERS *

By W. F. Garber

Laboratory Director, Hyperion Sewage Treatment Plant, Los Angeles, Calif.

The city of Los Angeles is discharging a treated sewage effluent into the littoral waters adjacent to one of the most used stretches of bathing beach in Southern California. To maintain adequate public health protection in this area, the Hyperion sewage treatment plant was built to give the tributary raw sewage complete treatment and "polishing" chlorination. With some variations, the situation is characteristic of many communities in California which discharge treated sewage through ocean outfalls. Similar conditions prevail on some inland streams where the problems may be made somewhat more difficult by the smaller quantities of diluting water and the use of the streams as potable, agricultural and industrial water sources.

Water Control Agencies

In California, there are two control agencies concerned directly with the quality of the waters adjacent to sewage outfalls. The State Board of Health examines the area in terms of public health needs and sets standards for the limiting acceptable bacterial population as well as for any other toxic substance. The State Water Pollution Control Board examines the area in terms of over-all best use and defines pollution in terms of the standards set by other control agencies.

Definition of Standards

The definition of standards and what constitutes pollution can be approached from several points of view. Three important ones are as follows:

1. That of the agency operating sewage treatment works which must necessarily be concerned with public health but which must also consider treatment costs, and is concerned lest the standards be unreasonably severe.

2. That of the public which is concerned with both aspects of this problem because it must expect to pay for the adequate treatment of the waste products it produces but should not be required to pay for over-protection.

3. That of the control agencies which are charged with the protection of the public health and must necessarily adopt a somewhat more conservative approach. They generally point out that the present standards are defensible from an epidemiological standpoint; that they often have the weight of legal opinion behind them; and that no better index of pollution is now known.

It is obvious that each of these viewpoints is valid and that the development of fair and adequate standards necessitates a study of them all. The operating agency must realize the need for a conservative approach because

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little is known about all the possible effects of sewage effluents in bathing waters and epidemiological studies are very difficult to make. The degree of treatment cannot be progressively reduced until significant epidemiological evidence is available. On the other hand, the control agencies must accept responsibility for the adequacy of their standards and the added cost of treatment, or the unnecessary enlargement or change in treatment works occasioned by too rigorous and unrealistic standards. It seems apparent that both these positions are tentative enough at the present time to suggest a compromise course.

The present standards are not challenged as the quantitative data needed for logical modification are not available. The purpose of this study is to reveal the problems faced by an operating agency. Anomalies in the present standards are cited and suggestions offered for a compromise acceptable to operating and control personnel. Information gathered at the Hyperion sewage treatment plant will be used as a reference range to which other data may be compared.

Initiating Study

To implement the study, a letter requesting information as to their present standards for natural, surface bathing waters was sent to the public health departments of each of the states and to other control agencies. The replies were compiled * and the analytical results obtained at the Hyperion sewage treatment plant were used to develop an index for the purpose of comparison. A study of the tabulated standards, the Hyperion data and certain other experimental work was then used to point out areas for further study.

As the study progressed, it became apparent that a fixed, unvarying standard was unrealistic in many ways and that the increased expense to operating agencies resulting from unduly harsh limits made a continuing research program on the subject desirable and necessary. As population increases and the load on the discharge areas becomes greater, the need for the description of logical but adequate limits will become greater. This is necessarily a concern of both the operational and control authorities, since the operating authority faced by increasing cost will become more critical of the present standards and the expense imposed by meeting these standards. The present basis for most standards must be resolved and the problem kept under continuous study.

Discussion of Study

Information Received

Thirty-eight state health departments and 9 other authorities replied to the questionnaire. Only the bacterial standards were then analyzed, as it was assumed that no gross evidence of sewage pollution would be evident, that dilution would be such that acceptable B.O.D. and suspended solids levels would be attained, and that the waters would be of a satisfactory chemical quality.

"How bacteriological standards were determined and why they were decided upon," seemed the most difficult query to answer. Several replies referred to the recommendations of the Joint Committee on Bathing Places (1) or to those of the state and regional organizations. The most frequent comment was that there was no analytical background for the present limits other than the fact that epidemiological experience under the standards had been good. This argument was used for standards ranging from a median

* Copies of the tabulated data from the questionnaire may be obtained directly from the author, Hyperion Sewage Treatment Plant, Los Angeles, Calif.

This tabulation also has been presented in "An Investigation of the Efficacy of Submarine Outfall Disposal of Sewage and Sludge." State Water Pollution Control Board, Sacramento, Calif. (1956).

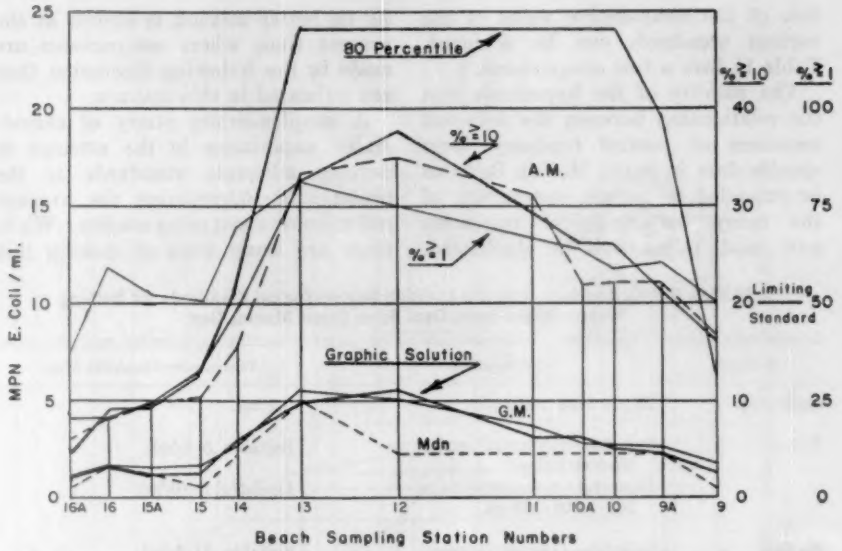

FIGURE 1.—Graphic comparison of beach water pollution indices, Santa Monica Bay, September and October, 1950.

M.P.N. of $< 2{,}400$ per 100 ml. to a requirement that no coliforms should be found. Most of these arguments have some validity. However, standards will continue to be questioned no matter how good the reasons until more analytically supportable background data are available.

Comparison of Standards

The bacteriological quality standards were so varied and complex that it was difficult to compare them. To obtain an approximation, beach counts obtained by the Hyperion laboratory on the waters of Santa Monica Bay were plotted, using several methods of measuring the average or index. Figure 1 shows these data, using arithmetic mean, geometric mean, median, graphic mean, per cent greater than or equal to 10 per milliliter and several others. With this curve available, it was possible to estimate the relationships between the measures of central tendencies most commonly used. Thus, lines perpendicular to the abscissa were erected in Figure 1 at the point where the curve for per cent greater than or equal to 10 per milliliter crossed the line indicating California limits. The values of the other measures at the point where they intersected the perpendicular lines were then assumed to be values affording equivalent protection. Table I shows what would be approximately comparable standards in Santa Monica Bay.

Using the values of Table I with representative standards, an estima-

TABLE I.—Values of the Various Indices Affording a Common Level of Protection in Santa Monica Bay

Type of Index	Approximate Value for Equivalent Protection
% ≧ 10/ml.	20% > 10/ml.[1]
% ≧ 1/ml.	60% > 1/ml.
Geometric mean	Means ≧ 2.5/ml.
Arithmetic mean	Means ≧ 9.5/ml.
Median	Medians ≧ 2/ml.
Graphic solution[2]	Graphic means ≧ 2.5/ml.

[1] California state limits.
[2] See reference (2).

tion of the comparative value of the various standards can be achieved. Table II lists a few comparisons.

The validity of the hypothesis that the relationship between the different measures of central tendency from specific data in Santa Monica Bay can be extended to permit comparison of the many bacteriological standards now used, might well be challenged. As no better method is known at the present time, where comparisons are made in the following discussion they are estimated in this manner.

A supplementary study of considerable importance in the attempt to develop adequate standards is the problem of determining the average pollution at a sampling station. While there are many ways of making this

TABLE II.—Comparison Between Limiting Bacteriological Standards for Bathing Waters Based Upon Data From Santa Monica Bay

Authority	Standard	Comparative Geometric Mean
California	20 per cent >10/ml.	2.5/ml.
T.V.A.	Suitable—Geometric mean 50–500/100 ml. Doubtful—Geometric mean 500–1,000/100 ml.	Suitable .5–5/ml. Doubtful 5–10/ml.
Hawaii	Suitable—Geometric mean 51–500/100 ml. Doubtful—Geometric mean 501–1,000/100 ml.	Suitable .51–5/ml. Doubtful 5–10/ml.
Illinois	Median coliform M.P.N. <700/100 ml. If enterococci M.P.N. ≥23/100 ml. Median coliform M.P.N. 700–1,000/100 ml. If enterococci M.P.N. <23/100 ml.	8.8/ml. ≥23/100 ml. 8.8–12.5/ml. <23/100 ml.
New York City	Suitable—Geometric mean 1,000–2,400/100 ml. Doubtful—Geometric mean >2,400/100 ml. with 50 per cent of samples >2,400/100 ml.	Suitable 10–24/ml.
Detroit	Median ≤500/100 ml. Maximum sample 2,400/100 ml.	6.3/ml. Maximum sample 2,400/100 ml.
Arkansas	Allowable arithmetic mean 1,000–2,400/100 ml.	3.0–7.2/ml.
Florida	Median ≤1,000/100 ml.	12.5/ml.
Oregon	Single sample >240/100 ml.	—
Michigan	Allowable median ≤2,400/100 ml.	30/ml.
West Virginia	Allowable arithmetic mean <1,000/100 ml.	3.0/ml.
Wyoming	Arithmetic mean <500/100 ml. Maximum 2,400/100 ml., 20 per cent >500/100 ml.	1.5/ml.
Virginia	Median ≤500/100 ml. with 10 per cent >5,000/100 ml.	6.3/ml. with 10 per cent >5,000/100 ml.

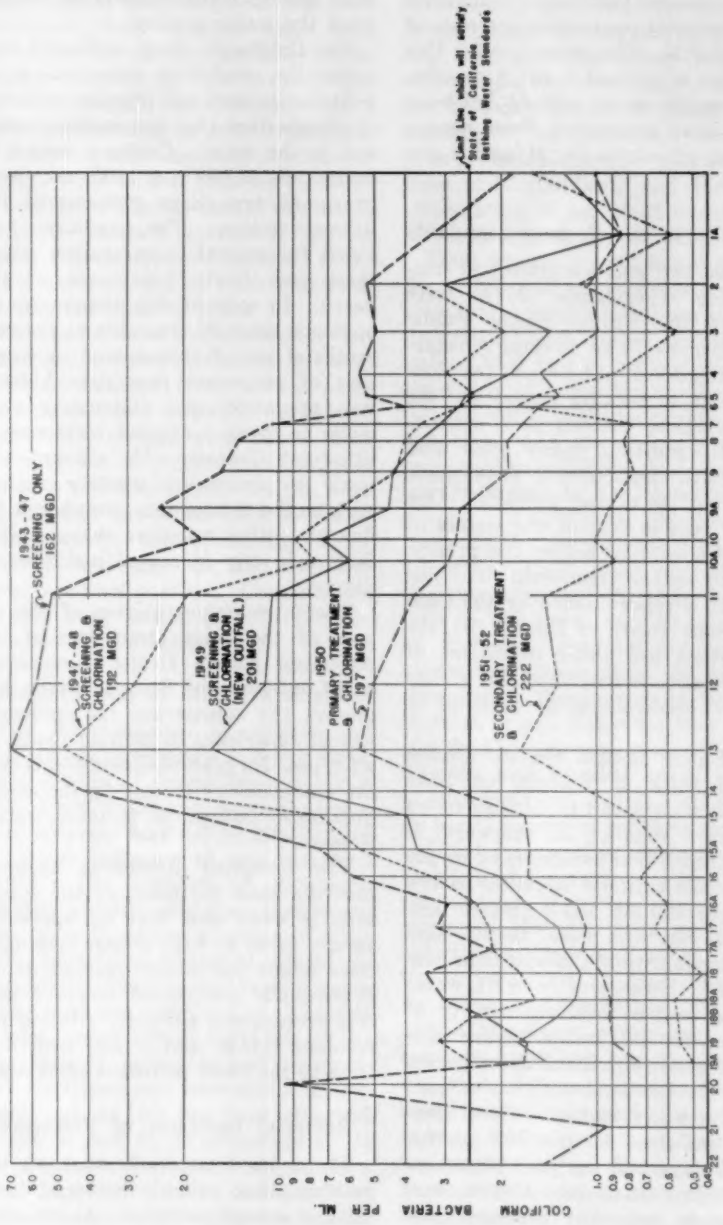

FIGURE 2.—Bacteriological analyses of Santa Monica Bay pollution abatement during September and October, 1943 to 1952.

average, the geometric mean most nearly measures the central tendencies of the bacterial population determined by the M.P.N. The reasoning for this preference is outlined in the Appendix. The geometric mean method has been applied in an evaluation of the sewage treatment process at the Hyperion site (Figure 2).

Anomalies in the Present Standards

At least two well-conceived and comprehensive experiments (3)(4) were made by the United States Public Health Service in an attempt to establish a relationship between the coliform index in bathing waters and the epidemiological pattern in a community. In addition, many state and local health departments have made partial studies of the problem. One familiar case is that of the waters of Santa Monica Bay before the present Hyperion sewage treatment plant was built. In a report issued by the California State Board of Health (5), the heavy beach use under conditions of gross pollution is described and a summary of epidemiological findings is given.

The Public Health Service studies included work at Chicago on Lake Michigan waters and at Cincinnati on Ohio River waters. In summary, it was concluded that swimmers in waters with median coliform densities as low as 100 per 100 ml, had a greater incidence of ear, eye, nose, throat, skin and gastro-intestinal illnesses than non-swimmers. Swimmers in river water having a median coliform density of 2,300 per 100 ml. had a higher incidence of gastro-intestinal disturbances than did those swimming in a pool where the water had a coliform density of less than 3.0 per 100 ml. for 36 of 39 days but the pool swimmers had a higher incidence of eye, ear, nose, throat and skin illnesses than did the river swimmers. It is important to note that authorities have pointed out that the incidence of such diseases among swimmers is higher than among non-swimmers no matter what the water quality.

The California study indicated that under the conditions examined, gross pollution existed and physical evidence of sewage discharge was on the beaches and in the water. Coliform counts in excess of 11,000 per 100 ml. were prevalent over large portions of the littoral waters. The condition persisted for several years, during which there was fairly heavy use of the beach. In spite of this, there were no epidemic diseases traceable to the recreational use of this water. A single case of suspected paratyphoid fever was presented and statements were made as to an increased incidence of intestinal diseases. No attempt was made to determine whether factors such as the tremendous population influx and other war-time changes were factors in any increased incidence of disease.

The introductory section of the report of the Joint Committee of the American Public Health Association and Conference of State Sanitary Engineers (7) summarizes the epidemiological experience in bathing places of all types. Its general conclusion is that the epidemiology describing the consequences of bathing in polluted waters is weak.

The foregoing discussion suggests that the basis for many of the standards is weak and that an operating agency faced by high sewage treatment costs might justifiably question them. It should be understood, however, that this presupposes adequate dilution for residual B.O.D. and solids, with bacteria as the chief pollutant remaining.

Bacterial Indicator of Pollution

There has been much work on the problem of a suitable bacterial indicator of sewage pollution. As interfering conditions may limit the value of the coliform group, other organisms have been examined. Enterococci (8)

(9) have been the alternate most often suggested but analytical problems have prevented their general use. One state (10) has set up standards which require a study of both the coliform and enterococci population, based upon the reasoning that concentrations of fresh sewage constitute the danger to public health and that the presence of residual coliforms should not necessarily be assessed against a bathing place. The enterococci are used to indicate the presence of fresh pollution, the dilution of it, or both.

The problem of differentiating between coliforms of natural occurrence, coliforms residual from earlier waste discharges, and coliforms associated with fresh sewage and hence more likely to be of public health significance, is a difficult one. Recent work (8)(9) has suggested that detection techniques for enterococci with a reliability equivalent to that for coliforms are now possible. Continuation of this work would help in the application of standards.

Interpretation of Coliform Results

The interpretation of coliform results suffers in accuracy in many ways. Since groups of organisms can result from land wash and animal origin, their presence may not be attributable to sewage pollution at any sampling station. The number of organisms can vary considerably from location to location, with waters adjacent to cities often containing the most organisms as a result of street washings, concentrated land use and the like. There is also the possibility of regrowth of the organisms if nutrients and temperature conditions are favorable. An extreme case of this has been observed by the author in an investigation of the effect of white water wastes from a small paper mill when discharged to a small creek (11). The sugars associated with the treated cellulose pulp were excellent media for the coliform group and coliforms rose to astronomical levels. Discharge of this waste was subsequently prohibited for the reason, in part, that the normal coliform index was unusable along the beach where the water eventually discharged and no real measure of pollution was available. The possibility of such regrowth is specifically mentioned in some state standards and the misinterpretation of resultant counts from this is cautioned against (12).

Even when regrowth is not a factor, the viability of the coliform organisms is such that results unrepresentative of the public health hazard are often possible. This fact is recognized in the standards of some states where it is pointed out that the pathogens may be less viable and are certainly less numerous than coliforms and that fresh sewage should be the material under control (10)(12)(13). Nusbaum and Garver (14), in their studies of San Diego Bay, Calif., have suggested that the concentration of coliform organisms in sea water may be a function of diffusion, coagulation and sedimentation rather than of viability. Apparently the organisms will exist in fresh or salt water for long periods if a food supply is present. The quick dilution and possible lower viability of pathogens would thus limit the public health hazard of coliform organisms residual from earlier discharges. The viability of the coliform group can be shown from Hyperion data. In the winter of 1952–53, when no polishing chlorination was used, strong offshore winds developed at times, persisting for three to four days. During this period the beach water was free of coliform organisms but the day after the winds dropped, almost 20 miles of beach water was very high in coliforms. Under normal conditions during nonchlorination a maximum of two to four miles of beach might show counts slightly in excess of the California standard. The organisms affecting the entire beach had been held offshore for a period of days. Simi-

larly, under different weather conditions and with no chlorination, points as much as 10 miles distant from the discharge point have shown high counts. Under these conditions the organisms had probably been diffused in sea water for periods in excess of that formerly considered sufficient to produce complete kills.

Some states make allowance in their standards for the degree of treatment given to sewage prior to discharge. Others make no differentiation, prohibiting water use within certain distances of any discharge point. The degree of treatment may be significant and a study of logical standards should include such an investigation. Table III will show very little change in the coliform population as sewage passes through the Hyperion treatment processes. However, there may be a shift through the secondary treatment section from typical *Escherichia coli* in the raw influent toward typical Aerobacter aerogenes in the final effluent. Whether there is a possible accompanying change in pathogens needs to be examined. Preliminary work at Hyperion with enterococci suggests this possibility.

The coliform group of organisms is also used to test the sanitary quality of certain foods. In most of these, the chief source of the bacteria is from those who prepare and handle food. Since this is a direct human source, it would seem likely that the possibility of pathogen transmission would be at least as great as that resulting from bathing in waters containing sewage effluent. To illustrate, the Army Quartermaster Corps (15) permits precooked-frozen food to have a standard plate count of 100,000 per gram and a coliform plate count of 10 per gram. The Interdepartmental Shellfish Committee of Canada (16) has suggested the following standards for shucked oysters received from the United States:

1. Acceptable—M.P.N. $\leqq$ 2,400 per 100 ml. and/or a standard plate count $\leqq$ 50,000 per milliliter.
2. Acceptable on condition—M.P.N. $<$ 160,000 per 100 ml. and/or a standard plate count $<$ 1,000,000 per milliliter.
3. Rejectable—an M.P.N. or standard plate count in excess of 2 above.

These food standards cannot, of course, be compared directly with those for bathing waters but the likely origin of their coliform population plus the possibility that the organisms will be ingested suggests that some of the bathing water standards might be too severe.

TABLE III.—Change in the M.P.N. of Coli-Aerogenes

Sampling Point	M.P.N. Per Milliliter	
	Arithmetic Mean	Geometric Mean
Raw sewage	400,000	317,000
Primary effluent	470,000[1]	410,000[1]
Secondary effluent, nonchlorinated	212,000	118,000
Plant effluent at discharge diffuser[3]	11,000[2]	6,000[2]

[1] Waste secondary sludge returned to primaries.

[2] With chlorination these counts are substantially less.

[3] Effluent discharged in 40 to 50 ft. of water, 5,000 ft. offshore.

Economic Considerations

The impact of overly severe standards upon treatment costs is of major concern to the operational authorities. These authorities wish to protect the public health but they would like to have some assurance that their efforts are warranted. The great range in the standards for coliform content allowed by the various states has been mentioned previously. In each case it was supposed that use of the standards had resulted in a satisfactory epidemiological experience. It was pointed out that there are often good reasons for the strict standards in that natural back-

TABLE IV.—Santa Monica Bay Bacteriological Data*

Sampling Station	Number of Samples		Per Cent Exceeding 10 Organisms Per Ml.		Geometric Average Count	
	With Chlorination	Without Chlorination	With Chlorination	Without Chlorination	With Chlorination	Without Chlorination
1	58	79	1.7	3.8	0.89	1.5
1A	66	70	0	5.7	0.52	0.95
2	66	71	4.6	9.9	1.3	1.5
3	67	71	1.5	11.3	0.64	1.4
4	67	71	3.0	9.9	0.75	1.8
5	67	71	3.0	11.3	0.71	1.8
6	67	70	0	11.4	0.60	1.9
7	66	69	1.5	15.9	0.61	2.2
8	68	71	0	18.3	0.68	2.2
9	67	71	3.0	18.3	0.68	2.8
9A	67	71	3.0	32.4	0.66	4.2
10	109	185	4.6	32.4	0.67	4.7
10A	104	188	0	32.4	0.60	5.3
11	177	177	0.6	41.2	0.71	7.2
12	177	186	2.8	50.0	0.69	12.4
13	178	186	1.7	53.0	0.73	15.4
14	176	185	2.8	45.4	0.79	8.1
15	178	184	1.1	26.1	0.52	3.2
15A	108	184	0	25.0	0.52	2.7
16	113	183	0	20.2	0.50	2.4
16A	67	71	0	12.7	0.52	1.4
17	67	71	0	12.7	1.9	1.2
17A	67	76	0	7.9	0.50	1.0
18	67	71	1.5	11.3	0.49	1.2
18A	67	71	0	7.0	2.1	0.90
18B	67	71	0	2.8	0.54	0.78
19	69	70	2.9	1.4	0.68	0.71
19A	66	71	0	2.8	0.57	0.71

* For the year ending June 30, 1954.

grounds may be low, population may be small, and lax standards might encourage poor practice. However, it seems illogical to require an operating authority to meet very strict standards when less stringent standards are satisfactory in an adjacent state.

In Table IV, the per cent of samples which contain more than 10 coliform organisms per milliliter and the geometric mean are shown for each of the regularly sampled stations along the 20 miles of beach immediately adjacent to the Hyperion sewage treatment facility. These data represent a year of normal operation and indicate the results obtained during a summer period when polishing chlorination was being used versus the winter months when the state allowed lower bacterial standards and no chlorine was used. It can be seen that with chlorination all stations were well below the California limit of no more than 20 per cent of the samples having coliform counts greater than 10 per milliliter. During the winter, however, the center third of the beach exceeded the limit with the worst station showing 53 per cent of the samples having counts in excess of 10 per milliliter. At this station the geometric average count was 15.4 per milliliter. Thus polishing chlorination kept all Santa Monica Bay stations within the legal limit but the worst station during the nonchlorination period was within the 30 organisms per milliliter geometric mean that some authorities now use to obtain satisfactory public health protection.

However, the problem cannot be completely covered by such a statement since the geometric mean method permits periodic fresh pollution with high counts to be leveled out by a series of low counts. A mean with a maximum count allowable is used by some states to cover such a possibility (10) (17) (18).

The Hyperion sewage treatment plant is now required to meet the California standard (Table II) each month of the year. This has necessitated polishing chlorination for about six months. To meet the stricter standard represents an annual cost of almost $150,000 for chemicals alone. Extra personnel and added maintenance are additional. Greater than the operational cost is the possibility that added capital investment in treatment facilities will be required to make compliance possible.

The public health significance of an increase in geometric mean M.P.N. such as that noted during the nonchlorination period is of concern to both the operating agency and the control authorities. Also, for the specific case cited, the present winter chlorination requirement should be continually re-examined to justify its cost to the people. The control agencies must modify their standards as other data become available. Some states specify that each situation be examined as a new problem and individual standards set (13) (19) (20).

Table V was developed from daily counts made along a portion of Santa

TABLE V.—Summary of Santa Monica Bay Beach Use [1]

Beach Section	Average Number of Bathers					
	During Chlorination Period[2]			During Nonchlorination Period		
	40% Max. Use	30% Intermed. Use	30% Min. Use	40% Max. Use	30% Intermed. Use	30% Min. Use
Section 1 (1.95 miles)[3]						
Avg. no. in water	204	35	2.4	22.5	0.3	0
Avg. no. in water/mile	102	17.5	1.2	12.2	0.15	0
Avg. no. on beach	1,025	295	79	336	58	7
Avg. no. on beach/mile	513	148	40	168	29	3.5
Section 2 (1.80 miles)[4]						
Avg. no. in water	11.5	0.7	0	2.8	0	0
Avg. no. in water/mile	6.4	0.4	0	1.6	0	0
Avg. no. on beach	123	26	4.6	30	5.4	0.65
Avg. no. on beach/mile	68	14	2.6	16.5	3	0.03
Section 3 (2.70 miles)[5]						
Avg. no. in water	329	79	5.3	25.5	0.7	0
Avg. no. in water/mile	122	28	1.9	9.5	0.3	0
Avg. no. on beach	1,454	470	92	336	53	6.5
Avg. no. on beach/mile	539	174	34	125	20	2.4
Avg. air temp. (° F.)	70.7	66.8	64.7	64.3	61.7	60.1
Avg. water temp. (° F.)	71.0	67.4	64.3	61.0	60.3	59.6

[1] Period Mar. 22, 1953 to Oct. 12, 1954. Daily count made from 11 AM to 2:30 PM.
[2] Chlorination period: May 15 through Oct. 31.
[3] Section 1—Ballona Creek to Imperial Highway (Hyperion Stations 10 through 12).
[4] Section 2—Imperial Highway to 45th St. in El Porto Beach (Hyperion Stations 12 through 15).
[5] Section 3—45th St. in El Porto to Manhattan Beach City Pier (Hyperion Stations 15 through 17A).

Monica Bay over a period covering two summer and winter seasons. The time interval in Table IV was included in the observations made. The chlorination and nonchlorination columns are divided into three sections. These show respectively the conditions observed during (a) 40 per cent of the time that maximum use was occurring, (b) 30 per cent of the time that minimum use was occurring and (c) 30 per cent of the time that intermediate use was occurring. The divisions were made to try to correlate air temperature with beach use. It can be seen that for almost 40 per cent of the time there was very little actual use of the water. The question then arises as to whether a public health problem is more probable under conditions of low use and a higher coliform index than under heavy use and a lower index. The question is particularly pertinent when winter coliform averages (Table IV) are compared with the beach use data (Table V) since the use is low and the coliform index is lower than the levels considered permissible by some authorities.

The problem of applicable standards for recreational waters under varying seasonal use has been considered by control authorities, and some standards provide for changes to be made at the discretion of the control officers. The data outlined in Tables IV and V suggest that seasonal relaxation of coliform requirements should be allowed. This presupposes that solids and B.O.D. reductions also are satisfactory. The maintenance throughout the year of standards of water quality intended for heavy-use conditions seems unreasonable, and results in unjust operational expense. In some portions of Southern California a paradoxical condition is possible. During the summer months a thermocline or thermal discontinuity exists in the ocean. Outfall sewers can be located and designed so that the thermocline, acting through temperature-density relationships, will hold the sewage discharge below the surface and thus reduce the effect upon adjacent recreational waters. During the winter when the thermocline is not present, the sewage reaches the surface and the influence of the discharge upon the shore is probably increased. A single year-round standard could thus result in the greatest treatment problems occurring during the winter when recreational use is at a minimum. Planning, which must be predicated upon the maximum treatment problem, is thus controlled by conditions occurring during periods of limited water use.

Summary and Conclusions

An attempt has been made to present a concept of the attitude an agency operating a sewage treatment plant or other source of waste discharge might properly take toward the bacterial standards required for the receiving waters used. The following points summarize in general terms the considerations important to this problem:

1. The attitudes of the waste treatment operating agency, the public health authority and the public must be considered with respect to the standards.

2. The operating authority must view a very wide range of standards all protecting the public health because they have shown a satisfactory epidemiology.

3. The operating authority often finds that the coliform test exhibits many anomalies and is not necessarily descriptive of the actual pollution. It seems that fresh pollution is what must be guarded against but no positive detection method is now available.

4. The operating authority may not be impressed by arguments that uncertainty should make the standards more restrictive because it knows that background coliforms may be present,

regrowth may be occurring and the viability of the control organisms is probably greater than that of the pathogens.

5. The operating authority must generally keep the characteristics of the receiving waters under constant study. If data indicate, it is logical and proper to suggest different or seasonal standards.

6. Control agencies should keep their standards under continuous study. If the standard cannot be varied with advances in knowledge and better understanding of discharge conditions, the control agency may be held responsible for the increased cost to the public.

The question then arises as to what can be done to make and keep the standards logical and still give adequate public health protection. The following suggestions are made:

1. Review each case separately rather than in terms of a fixed unvarying standard. Most states have many types of conditions within their boundaries, and a single yardstick might not be adequate.

2. Study the problem of public health hazards versus water use, trying to resolve the question of the degree of danger presented by minimum use and moderate coliform counts versus maximum use and low coliform counts. It is assumed that chemical, B.O.D. and solids quality is acceptable with only bacterial pollution considered.

3. Research should continue and be pushed vigorously on other more suitable indices of fresh pollution. The current work on enterococci seems promising.

4. Control and operating agencies should work for comprehensive and continuing research by groups such as the Public Health Service and water pollution control boards to try to develop a group of parameters by which the surface waters in any locality or region can be more quantitatively examined for public health hazard.

5. The least stringent standard now routinely used should be provisionally accepted, since it presumably has a suitable epidemiology and has proved adequate in use. This is no more than can be said for many other standards. Regions of high and low background counts might be reevaluated.

Acknowledgments

Appreciation is expressed for the statistical analysis of bacteriological data by C. G. Gunnerson, Associate Civil Engineer, Bureau of Sanitation, Los Angeles. The valuable help and suggestions of the following staff members of the Hyperion sewage treatment plant, Los Angeles, Calif., is also gratefully acknowledged: Joe Nagano, Chief Chemist; William Otto, Water Biologist; G. A. Parkes, Chief Engineer; R. D. Bargman, Assistant Chief Engineer; J. M. Betz, Civil Engineer; and George Callahan, Assistant Civil Engineer.

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APPENDIX—JUSTIFICATION OF THE GEOMETRICAL MEAN METHOD

Per cent of samples containing 10 or more coliform bacteria per milliliter

Advantages:

1. Method for many years.
2. Easy to calculate.

Disadvantages:

1. All M.P.N. over 10 are given the same weight.
2. Implies no pollution (*i.e.* 100 per cent treatment efficiency) when all samples show less than 10 coliform per milliliter.

Arithmetic mean of M.P.N.

Advantages:

1. Easy to calculate and understand.
2. Recognized by APHA, AWWA and FSIWA in "Standard Methods."

Disadvantages

1. Greatly influenced by extremes, especially large.
2. Where arithmetic mean differs widely from median or mode, may not be representative.

Geometric mean of M.P.N.

Advantages:

1. Relatively insensitive to extremes.
2. Provides most nearly regular pollution curves.
3. Limits the effect of high counts, recognizes that some high counts are inherent in the procedure and must therefore be, in effect, neglected.
4. Best measure of central tendencies of a geometric function such as the M.P.N.

Disadvantages: Not readily understood.

Median

Advantages: Easily explained.

Disadvantages:

1. Completely insensitive to extremes.
2. Restricted to actual M.P.N. values; *i.e.* will commonly have large variations for adjacent stations.
3. Breaks down when large number of samples show same M.P.N.

Mode

Advantages: Most natural of all concepts.

Disadvantages:

1. Meaningless when occurring at M.P.N. values of 0.45− or 70+.
2. There are often two, and occasionally three, modal values.

Other Methods

1. Quadratic mean (root-mean-square) is even more sensitive to large extremes than is the arithmetic mean and is difficult to explain.
2. Harmonic mean (reciprocal of arithmetic mean of reciprocals) is also sensitive to extremes, especially small. Its main use lies in rate or time studies.
3. The 80-percentile method is extremely erratic and difficult to analyze.

The geometric mean provides an average that is relatively insensitive to extreme values. When plotted for Santa Monica Bay over a 10-year period, it provides a resaonable indication of the results of sewage treatment.

MEETINGS OF INTEREST
1956

June 4–8 **American Society of Civil Engineers,** Knoxville, Tenn.

June 18–22 **Gordon Research Conference on Stream Sanitation,** Kimball Union Academy, Meriden, N. H. Dr. W. George Parks, Director, Gordon Research Conferences, University of Rhode Island, Kingston, R. I.

June 18–23 and 25–30 **Bioxidation of Organic Wastes,** Manhattan College, New York, N. Y. Assistant Professor W. Wesley Eckenfelder, Civil Engineering Dept., Manhattan College, New York 71, N. Y.

June 26–28 **Interstate Sanitation Seminar,** 10th Anniversary, Williamsburg, Va.

Aug. 20–31 **Massachusetts Institute of Technology.** Disposal of Industrial Wastes by Biochemical Processing. Summer Session. M.I.T., Cambridge 39, Mass.

Aug. 22–24 **Hydraulics Division, American Society of Civil Engineers,** University of Wisconsin, Madison, Wis. Professor Arno T. Lenz, College of Engineering, University of Wisconsin, Madison 6, Wis.

Oct. 8–11 **Federation of Sewage and Industrial Wastes Associations,** Los Angeles, Calif.

Oct. 8–12 **Bavarian Biological Institute,** Munich, Germany. Advance course in biology of sewage and stream sanitation. Dr. H. Liebmann, Bayerische Biologische Versuchsanstalt, Veterinarstrasse 13, Munich 22, Germany. Applications by Sept. 22.

Oct. 15–19 **American Society of Civil Engineers,** Annual Meeting, Pittsburgh, Pa.

Nov. 12–16 **American Public Health Association,** 84th Annual Meeting, Atlantic City, N. J.

Nov. 19–20 **Sanitary Engineering Division Conference,** American Society of Civil Engineers, Kansas City, Mo. A. D. Caster, Division Secretary, 38 Arcadia Place, Cincinnati 8, Ohio.

THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

ODOR POLLUTION

Few sewage treatment plant operators have escaped the nuisance problems incurred by the production of obnoxious odors either at the treatment plant or throughout the sewer system. Today, at meetings where sewage treatment personnel gather, the discussion subject that ranks with digester scum problems is the problem of odors. Articles in this section of the Journal have indicated something of the prevalence and complexity of the odor problem.

The problem of odor control has been more frustrating and will be far more expensive to solve than the problem of digester scum control. Odors affect the entire community in one of its most sensitive and personal areas—the nose. The problem demands immediate attention at the level of each individual plant and from the profession as a whole if we are to avoid deterioration in our public relations.

Public awareness of the odor problem and the resulting demand that something be done about it, have resulted from several factors, among which are the following:

1. Increase in the number of treatment plants constructed through increased emphasis on water sanitation.

2. Tremendous increase of interest in air pollution and air pollution problems. To the lay public, air pollution and odors are one and the same tning. So if it smells—its air pollution.

3. Promotion of the idea that a well-operated treatment plant is odorless. The idea is prevalent that one may live within view (smelling distance, too) of a treatment plant and never have an odor nuisance. As a result, residences have been constructed too close to treatment facilities.

4. The current conviction that, with today's scientific miracles, there is no reason to put up with odors.

Today's sanitary engineering and waste treatment personnel are faced, in some locations, with the necessity of incurring considerable expense to control odors. Nuisance odors cannot be reduced by one-half or three-quarters; they must be eliminated entirely. For, once the public is odor conscious, nothing but sweetness or complete odorlessness will be permitted.

But what is really known or understood by the profession concerning the technical nature, dissemination and control of sewage-related odors? Good plant housekeeping, particularly cleanliness, is agreed upon as the first line of attack. Thoughtful and skillful design rates high as does the provision of adequate funds to provide good treatment facilities and adequate control. However, more information is needed on the nature of the odor problem, the effectiveness of controls, especially odor masking agents and counteractants. Then a wider dissemination of information on a local and national level is needed.

To this end the Federation can serve an important role. Although the Federation does not concern itself with the field of air pollution, it must become active in the problems of odor pollution from sewage origin. The stimulating of comprehensive fundamental research at this time when the entire problem of air pollution is in the forefront of public and scientific thinking is most appropriate.

The sewage and industrial waste profession must not be guilty of the paradox of cleaning up the waterways while polluting the atmosphere. Action is needed before this problem reaches the magnitude of the steam pollution problem.

D. P. S.

THE PLANT OPERATOR AND PUBLIC RELATIONS *

By George T. Lohmeyer

Superintendent, University of Florida Sewage Treatment Plant, Gainesville, Fla.

Few short schools for water and sewage treatment plant operators are scheduled today without including the topic of public relations. Why do the planners of operator training courses include this topic? Why is it important?

One main reason this topic is generally included is that the experienced sewage treatment plant operator demands it. The topic is important because without paying attention to improving plant public relations, even the veteran plant operator will be handicapped in meeting his responsibilities.

Public relations refers to the overall feeling the citizens in a community have toward the local sewage treatment plant. This feeling can vary from complete indifference, which is the general public attitude if the operation of a plant is completely satisfactory, to bad, if a plant has given the slightest grounds for complaint. No treatment plant has or will have a commendable public relations program without directing some effort towards this goal. It will never just happen, work is required!

With the exception of rare geniuses, few successful men in history have been able to completely ignore the public. Large industrial concerns and branches of the armed services have public relations experts whose full-time jobs are to improve relations with the public.

The attitude the public feels toward a sewage treatment plant can affect that particular plant's operation in several ways. Although a number of privately owned and operated sewerage works are in existence, the majority of such services are provided by municipally operated utilities. The elected or appointed officials charged with setting up budgets for these facilities have an easier job if the public has a high regard for the sewage treatment plant.

Plant Appearance

Beautifying a plant exterior must not be overlooked in bettering public relations, even though a large part of the public will unfortunately never take the time to observe a plant first hand. They will never see the excellently prepared monthly operation report, and if they did it would be of little significance. What the public sees on the outside will be the basis for its judgment. Consequently, it behooves every operator to create a plant of pleasing exterior qualities. Would a visitor to your plant today find a well graded and planted lawn surrounding a neatly painted control building and treatment units?

Operator Appearance

In sewage treatment, as in all jobs, there is no place for untidiness in the appearance of employees. An excellent impression given a plant visitor by a beautiful plant exterior can quickly fade if the plant operators are sloppy in appearance. Several Florida sewage treatment plants furnish operators with laundered white uniforms. Naturally, visitors are impressed with so fine a showing of organized neatness. Uniforms are not absolutely necessary, all that is required in this respect is that the operators work in clean clothes, and by all means come on the job with a clean shave. An operator who is dirty and unshaven ruins not only the prestige of his own plant but the prestige of his profession as well!

* The *Overflow*.

Plant Courtesy

Regardless of the importance or seeming unimportance of a visitor to a treatment plant (and who can be a judge of this) each person should be treated with the utmost respect and courtesy. Operators too busy at the time to properly show a visitor through the plant should invite the person to return at a more convenient time. Every plant should have a visitor's registry and every visitor should be invited to sign. Visitors should be made to feel that they are welcome and their visit appreciated. Furthermore, every question asked should be answered with tact and respect.

A good operator naturally reveals that he is proud of his job. He realizes his work is one of the most important phases of public health and for that matter preventive medicine itself. How can a citizen-visitor feel proud of the local sewage treatment plant if the man who shows him about the plant creates the impression he is on the job only to draw a pay check.

Use of Proper Terms

Plant visitors are impressed not only by the treatment facilities but by the manner in which the plant is described. Thinking operators have found it wise to arrange standard "tours" for displaying their treatment plants. In showing a visitor through a plant it is best to follow the flow-through route. Each treatment process, type of sewage treatment plant and treatment unit has a proper technical name. Only the correct terms should be used in describing the plant.

An operator should know more about his plant than anyone else. Ready answers should be given on questions pertaining to the plant history, design engineers, the builder, design capacity, capacity of units, analyses of the raw and finished product and other details of the plant units.

Plant Interest

In addition to maintaining a sewage treatment plant attractive by keeping it immaculately neat, it is also possible to make it interesting. Visual aids, displays and diagrams have been prepared by alert operators to make their plants more easily understood by the layman. An aquarium of tropical fish provides a point of keen interest to anyone. But consider the significance of such an aquarium, in a complete sewage treatment plant, that is fed by the plant effluent (before chlorination, of course). Displaying plant models, or a series of pictures taken during various stages in the plant construction has been found effective in creating interest. Flow-through diagrams of the treatment units or maps of the city and its sewer system also are helpful.

The average lay visitor does not appreciate the technical nature of sewage treatment plant operation. There is a tragic lack of understanding on the part of the public as to what is being done by various agencies, institutions and professional societies to improve the general quality of plant operation. Operators can do much to assist in this endeavor by displaying plant operation awards earned by their plant, together with individual certificates of operation earned by plant personnel. Certificates of membership held by the operating personnel in the various professional societies likewise should be on display in a prominent place.

Off-the-Job Relations

The attitude of the public towards the local sewage treatment plant may not be obtained entirely by in-plant activities. The people of the United States found after the last war that some of their best ambassadors were G.I.'s who were constantly meeting the citizens of other countries. In the same way, a plant operator in his off-duty hours can do much to better the feeling the public has towards the opera-

tor's occupation. In his church, in his local businessmen's club, and in all phases of community activity the plant operator can do much to forward good public relations.

Public relations is a frequently used term. On a personal basis good public relations comes naturally to some people. They are the ones voted in their school classes as most likely to succeed. However, to others maintaining good public relations is a real effort, but it is a program that will pay dividends.

HOW TO CARRY A MUNICIPAL BOND ISSUE*

By Austin P. Hancock

President, Texas Construction Council and City Manager, Abilene, Texas

Facts, plainly and frankly stated, are the best "salesmen" with which to get voter approval of a proposed city bond issue. They should anticipate and concisely answer every question which could conceivably be asked by any citizen regarding the bonds and the projects to be financed.

But before facts can be put to work successfully in the campaign, certain qualifications must be met by the planned construction projects and by the city itself. These are:

1. The improvement program must be needed.
2. The governing body of the city must sponsor the proposal.
3. Planning of the construction program must be thorough and in enough detail to explain to the voters so they can understand it easily.

After the program has been agreed upon by the city commission or city council, the support of the local Chamber of Commerce and leading citizens should be sought by presenting the facts. This can be done best by meetings with the board of directors and special committees of the Chamber of Commerce and in private discussions with the community leaders. At this stage the press, and radio and television stations should be taken into confidence.

After the endorsement of the program by the Chamber of Commerce, leading community leaders, press, and radio and television stations, has been assured, the program is ready to be officially announced by the city's governing body. In making this public announcement, it is important that someone shall have anticipated all of the objections which various groups and individuals might raise to the program and will be ready with the correct answers. If someone can successfully anticipate the objections and answer them before they are made, the battle is half won. If the program is needed, sound and well planned, this task isn't difficult for a person thoroughly familiar with the plans.

The question-and-answer method of presenting the facts for a construction program has been found effective in promoting a bond issue. One very effective way to make the first public announcement is in the form of a large newspaper display advertisement (a half page or a full page) listing every conceivable question about the proposed bonds and the construction to be financed, each question followed by the answer. This gives every reader a complete picture of what is being submitted to the voter. Many readers will tear the ad out and save it for repeated references prior to election time.

An example of the effectiveness of

* Extracted from *Plans and Specs*, **3**, 12 (1955).

this method was demonstrated during the campaign to obtain voter approval of a $6,650,000 bond issue for the city of Abilene, Texas in 1954. Publicity was started with a full-page, question-and-answer advertisement in the local newspaper. The Abilene Chamber of Commerce published a printed pamphlet containing the main bond issue facts in a briefer form. The Abilene newspaper and the radio and television stations carried on their own series of articles and programs about the improvement projects planned and the bonds that were to finance them. Speakers appeared before the civic organizations. The issues carried by an average of 10 to 1.

Some of the things that the taxpayer wants to know and should be told are:

1. How much will the tax rate or utility rates be raised? How much will the program cost?
2. Why are the improvements needed?
3. Where will the improvements be constructed?
4. If a large issue, will all the bonds be sold at one time?
5. How will the bonds be sold, public or private sale?
6. If the program contains a number of projects, what is the estimated cost of each project?
7. What is the order of construction? Why?
8. How will contracts be awarded?
9. How long will it take to complete the program?
10. Will the bond issue include all costs, such as land, right-of-ways, engineering and architect fees?

In order to be able to anticipate all questions, contact must be made with a cross-section of all the people of the city. After a complete set of questions and answers has been prepared and published, it is up to the press, radio and television stations and a special speakers' committee to keep the public informed and to get them out to vote.

The mayor and city commissioners or councilmen must take the lead in sponsoring the campaign and actively support the program at all times. It won't do to pass responsibility for the bond program to the Chamber of Commerce or some other citizens' committee; the city's governing body must believe in and fight for the program.

PIPING COLOR CODES

The Subcommittee on Paints and Protective Coatings of the Federation is actively planning a painting manual adapted to the particular problems confronted at sewage and industrial waste treatment facilities. Interest in color codes for treatment plant piping has been expressed by several member associations and a number of operators and designers. Piping color codes evoke interest every time a new sewage treatment facility is designed and constructed, or when a plant superintendent plans a painting schedule for his installation.

In 1954, the California Sewage and

EDITOR'S NOTE—Adoption of a recommended color code for use at sewage and industrial waste treatment plants would serve a useful purpose. However, such a code must consider all available studies of merit and incorporate, insofar as possible, the opinions of fact as presented by operating personnel. To further this purpose the accompanying article is presented for consideration and comment by the readership. Your comments should be directed to Kerwin Mick, Chairman, Subcommittee on Paints and Protective Coatings, Minneapolis-Saint Paul Sanitary District, P. O. Box 3598, Saint Paul 1, Minn.

Industrial Wastes Association appointed a committee to study piping color codes in an effort toward the development of a color scheme for consideration by the association membership. While this study was being undertaken the state of California adopted a standard pipe marking and safety color code for use at state-owned properties. This code is based on the standards for piping color codes in industry as developed by the American Standards Association, National Safety Council and American Society of Mechanical Engineers. The work of these professional groups has been comprehensive and provides an excellent basis upon which to prepare a specific color code for the sewage and industrial wastes field. Inclusion of a recommended color or other identification code is planned by the Federation's "Paint Manual" Subcommittee.

In further consideration of piping color codes excerpts from the color code for the state of California are presented for consideration.

CALIFORNIA STANDARD PIPE MARKING AND SAFETY COLOR CODE

Need for Color Code

The need for a systematic and uniform method of identifying materials contained in pipes throughout all state properties has been apparent for so many years that further justification should be unnecessary.

One reason supporting this need is to have maintenance and construction personnel readily familiar with piping even though transferring from one institution or property to another. This in itself would conserve incalculable amounts of time, and therefore money, for the state. Another reason supporting this need is to permit quick familiarization by outside personnel in the event of major disaster or calamity such as fire, flood, earthquake, bombing or other unforeseen event.

At the present time, if it became necessary for Civil Defense, National Guard, Army, Navy or other agency to assume the operation of any state properties on an emergency basis, operating personnel would be severely handicapped in attempting to orient themselves. Much unnecessary and perhaps dangerous confusion would result due to lack of piping identification.

This system was set up with the thought that it should be inexpensive to install, require a minimum of effort to maintain, be simple to become familiar with and be all-inclusive in scope, as well as most effective.

The Color Code

Table I presents the basic features of the piping system identification method, including the classification letters, class description, color and special uses for which each class is designated. This method is to be used as the standard safety color code for the entire scope of purposes for which pipe markings will be necessary. Specific material classifications and recommended legend, color and banding are given in Table II as they may be applicable to sewage and industrial waste treatment facilities.

Material Classification

This column gives the classification letter for the material conveyed in the pipe as approved by the American Society of Mechanical Engineers, American Standards Association and National Safety Council and is not to appear on the piping.

TABLE I.—Basic Features of Piping System Identification

Classification	Description	Color	Special Uses
F	Fire protective	Red	Danger
D	Caution	Yellow	Caution
D	Alert	Orange	Electrical
S	Safety	Green	Safety
P	Protective	Blue	Protection
—	—	Brown	Waste lines

TABLE II.—Standard Pipe Marking and Safety Color Code

Material Classification	Printed Legend with Direction of Flow Arrow	Color Code	Additional Safety Banding
S	Domestic water[1]	Green	3-Green
S	Industrial water[1]	Green	1-Green
F	Fire protective water	Red	1-Green
D	Hot water supply or return (domestic)	Yellow	1-Green
D	Hot water supply or return (heating)	Yellow	1-Green
S	Distilled water	Green	1-Green
D	Boiler feed water or blow-off water	Yellow	1-Green and 1-Yellow
D	Pressure steam	Yellow	2-Red
D	Acetylene, butane, exhaust or flue gas	Yellow	3-Red
D	Gasoline	Yellow	3-Red
D	Manufactured, natural, propane or process gas	Yellow	3-Red
D	Fuel oil or diesel oil	Yellow	2-Red
D	Chlorine	Yellow	2-Red
D	Oxygen	Yellow	2-Red
S	Compressed air	Green	1-Yellow
S	Vacuum air	Green	—
—	Sanitary sewer, raw sewage influent	Brown	—
D	Danger, electrical (exact voltage)	Orange	3-Red

[1] "P" or "NP" after legend indicates whether potable or non-potable water.

Legend

This column shows the printed legend, as it shall appear on the pipe in conjunction with the direction of flow arrow pointing in the direction of flow. The legend is the mandatory portion of the system.

This printed legend with the direction of flow arrow must appear as specified to conform or qualify as a standard pipe marking code.

Banding

Banding shall be used when it is deemed necessary or desirable to include banding of piping in classification colors.

One-inch colored banding shall be applied on the piping 1 in. from the immediate *left* of or preceding the stenciled legend and direction of flow arrow. The banding shall be as follows:

Primary mains	Three 1-in. bands
Intermediate or secondary mains	Two 1-in. bands
Branch mains or equipment service	One 1-in. band

Color

This column identifies the classification color as approved by the ASME, ASA, and NSC for each material as listed. The identifying colors, red, yellow, orange, green, blue and brown, shall apply for whatever materials are used; paints, cellulose tapes, fibered tapes, gummed paper or other.

The classification color shall be used when painting identification bands or the entire pipe should it be deemed desirable to use this latter type of system. However, when the entire pipe is painted a band of ample width to accommodate the legend portion of the system shall be provided in white or pastel color in ample contrast to any of the classification colors as to be readily distinguishable.

Additional Banding

This column gives the additional banding to be used in the event supplemental safety or precautionary marking proves necessary or desirable. It should be noted that the band size called for is ½ in. in width. These bands shall be placed ½ in. apart

where more than one band occurs, and commencing 1 in. to the immediate *right* of or after the printed legend and direction of flow arrow. This additional banding is designed to indicate such things as the danger or safety of the material carried as pertains to its degree of explosiveness, inflammability or danger to life and limb. For example: three ½-in. red bands would indicate an explosive material, two ½-in. red bands an inflammable material, one green band a very safe material, etc.

On small pipes with outside diameter of 2 in. and less, the height of letters used shall be equal to approximately one-half the outside diameter of the pipe, *i.e.*, ½ in. on 1-in. pipe, and 1 in. on 2-in. pipe. On larger piping, the same rule shall prevail up to the use of a maximum size letter of 3 in. in height. The printed legend shall appear at all valve locations, wherever and whenever a pipe passes through an obstruction, both at the point of entry into and/or egress from or within a reasonable and convenient distance therefrom (a reasonable distance being within 4 ft.). Wherever two or more pipes run parallel, the printed legend and other markings shall be applied in the same relative location so as to be in either vertical or horizontal linearity, whichever the case may be. The printed legend, with direction of flow arrow, shall appear as many times as is necessary along the pipe to be readily conspicuous at all times from any reasonable point of view.

All pipes shall be marked at both ends if the total length exceeds 10 ft. No piping shall run more than 30 ft. between markings, except in cases where the pipe is so located as to preclude this necessity. This would be if the pipe were confined to a tunnel, run overhead for long distances, or buried, in which case common sense and good judgment of needs shall be considered.

Instructions and Suggested Methods of Application

The use of paper stencils for the printed legend should present little or no problem. In case of smaller installations, arrangements can be made with a place of business having a shipping department to cut a nominal amount of paper stencils for little or no charge. The stencils should be attached to the pipe and made to lay closely with the use of masking tape. Stencils thus attached can be sprayed with paint and, on removal, should result in a sharp, clean edged printed legend.

Paints for lettering, as recommended, are available in pressurized cans. The use of paint materials packaged in this manner is recommended, as there will be no labor required for mixing and preparation of paints or usual messy clean-up work on completion. Also, these paints can be on hand for additional marking work as may be necessary at any later date.

Tapes, in colors corresponding to the standard colors, are available in widths as specified for the color banding. These colored tapes are manufactured expressly for the purpose of pipe marking, and the fiber types are quite durable.

By following the foregoing recommendations and specifications, no special skills are required to apply this pipe marking system. Any man in the maintenance staff possessing the qualities of neatness and normal mechanical ability should be capable of pipe marking without assistance, except perhaps a man not familiar with the piping who therefore would need to have the various pipes named as to contents by someone on the mechanical maintenance staff.

Other Uses

The safety color code portion of this system is intended for use throughout any installation. The uses to which

this color code can be put are numerous. It could be used in various shops to mark off locations that are safe, hazardous, or dangerous; to paint electrical switch boxes (orange); "No Smoking" signs (white lettering on red background); first aid equipment (green); protective equipment (blue); etc. Containers for various liquids such as gasoline cans (red); water (green); etc., can be marked in any and all areas of institutions to indicate danger, caution, alert, safety, and the protective status of the container or item.

UPPER MISSISSIPPI RIVER—GREAT LAKES BOARD

The Upper Mississippi River—Great Lakes Board of Engineers, representing 10 states, has suggested the following standard color schemes for sewage treatment plants:

Piping	*Color*
Sludge	Brown
Gas	Red
Potable Water	Blue
Chlorine	Yellow
Sewage	Gray
Compressed Air	Green

This is a relatively easy list of colors to remember and the choice of colors appears logical. There is a natural association in the minds of most operating personnel between the color noted and the material conveyed. The system avoids the use of a band or legend, thereby making it well suited for small plants or uncomplicated pipe systems. Directional flow arrows, however, are desirable.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"He who would climb a tree must grasp its branches—not the blossoms."—Anon.

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

First Annual Report of the Columbia Borough, Pa., Sewage Treatment Plant

By Lewis B. Scherer, *Superintendent*

Although the Columbia Borough Sewage Treatment Plant has been in operation since mid-1953, this is the first operation report. The present superintendent has been in charge of plant operations since March, 1955.

The treatment plant is designed for primary treatment and effluent chlorination. Two 45-ft. diameter floating cover digesters provide adequate sludge digestion capacity. The average raw sewage flow is 0.69 m.g.d. and, during heavy flash storms, increases to approximately 2 to 3 m.g.d. During these storms the operator must open the bypass around the comminutor to prevent flooding of the plant yard. This excess flow is due to surface water entering the sewer through roof drains, manholes and cellar drains.

Sewer System

Maintenance work on the sanitary sewers has increased every year since the original sewers were laid in 1933. Unfortunately, they have received no

attention until just recently. A definite maintenance schedule is being drawn up to cover every section of town so that all sewer lines will receive a cleaning once every two years. Tree roots are the biggest problem and have caused considerable line breakage. At present a chemical cleaning agent * is used to combat roots in the lines. This product was chosen for its ability to open line stoppages. Also it is harmless to the treatment plant since it does not contain acids or copper and is alkaline in nature.

Industrial Wastes

The citizens of Columbia Borough are under the impression that primary sewage treatment plants will handle any type of waste that can be discharged into a sewer. Through the use of local newspapers and inspection tours, effort is being made to re-educate the people. The local schools have helped considerably by arranging for students to tour the treatment plant during school hours.

An industrial waste survey was conducted to find out what the local industries were discharging into the system. Only five of the industries surveyed required pre-treatment of their wastes.

A local potato chip manufacturer discharged potato waste directly into the sewers. This waste consisted of potato sprouts and peelings which amounted to several tons per day. The sprouts caused frequent clogging of the bar screen and rapid dulling of the comminutor. On some days it was impossible to pump these potato wastes and lines had to be backflushed to open them. The potato chip factory has cooperated and installed screens to eliminate some of their waste. After installation their B.O.D. load dropped from 2,700 p.p.m. to 1,500 p.p.m. and their suspended solids from 469 p.p.m. to 250 p.p.m.

Another source of pollution was a local silk textile mill which dyed silk. The treatment plant would receive red, green, blue and black dyes at periodic intervals. These dyes would discolor the primary tanks and cause considerable discoloration of the Susquehanna River. The textile company has installed treatment tanks and now treats the dye waste prior to discharge to the sewers. Activated carbon, alum and lime effectively remove the color from this waste and aid in controlling the pH.

The greatest source of trouble encountered was the local malleable castings company which discharged spent pickling liquor. At times the volume of this waste amounted to 10 per cent of the total flow to the treatment plant and it had a pH range from 1.5 to 5. After discussing this problem with the company engineer, it was decided that they would put in their own treatment plant for treating the pickling waste and the city would still handle the sanitary waste. This agreement has worked satisfactorily for all parties concerned.

Operation

Treatment at the plant has been quite difficult due to the type of wastes received. Fortunately, most of this difficulty has been eliminated through the industrial wastes survey.

Both digesters were operating in an acid stage; one at an average pH of 5.6, the other at a pH of 5.1. It was apparent that the digesters were stuck due to a heavy scum accumulation which varied from 5 to 8 ft. in thickness and was solid enough to support a man.

On June 26, during one of the worst heat waves on record, both digesters were full of partially digested sludge. No supernatant could be withdrawn, so the decision was made to empty one digester to the drying beds. Each of the six available beds (40 ft. by 80 ft.) was filled to a depth of 18 in. in order to empty as much of digester No. 1 as

* Sanfax No. 222.

possible. No supernatant level was found during the emptying of this digester. After five days of pumping to the beds the cover was on its stops and the scum was resting on the bottom of the digester. It was impossible to remove this scum by using water and on July 6, after many unsuccessful attempts, the cover was refloated with the scum still in the digester.

The sludge on the beds created quite an odor problem but, due to advising the people of the difficulties by newspaper, very few complaints were received. Within two weeks the sludge was dry enough to remove and was hauled to a local farm. Sufficient digester capacity was then available to continue operations until a plan could be prepared for removing the scum.

A tank truck was purchased at a cost of $4,000 to permit the hauling of liquid sludge and to eliminate the odor problem encountered in disposing of partially digested sludge. August 1 work began on emptying the No. 2 digester, using the tank truck and hauling the sludge to local farmers at cost. The No. 2 digester was almost completely emptied except for a 3-ft. scum layer. This scum is being dug out by hand and hoisted by bucket to the digester roof. From there it is hauled to a ditch dug on the plant grounds. An electric hoist, used for handling chlorine cylinders, was erected on the digester and has proved to be a real back saver. When this digester is completely emptied it will be cleaned and put into service by reseeding with digester sludge from a neighboring treatment plant.

Revenue

The sewage treatment plant was built by the Columbia Borough Municipal Authority which, in turn, leased the treatment plant and the sewer system to the Borough.

Yearly income is derived from sewer charges based on 80 per cent of the established water rates. Total expenses for the fiscal year 1955, including authority expenses and bond payments, amounted to $93,319. A profit of $3,219.88 was made during the year which was about $2,000 more than the anticipated profit estimated in the budget for 1955.

A much better year is expected in

TABLE I.—Summary of Operating Data for the Columbia, Pa., Sewage Treatment Plant for the Year 1955

Item	Average	Item	Average
Connected population	13,000	Volatile solids (%)	89.0
Equivalent population	18,000	Digested sludge:	
Flow (m.g.d.)	0.69	Volume withdrawn	600,000
pH:		Moisture (%)	20.0
Influent	7.2	Volatile solids (%)	80.0
Effluent	7.1	Gas production:	
Screenings (cu. ft. per day)	2.0	Cu. ft. per day	6,000
B.O.D. (p.p.m.):		Methane (%)	20.0
Influent	520	Operating expense ($):	
Effluent	320	Salaries	13,700.07
Reduction (%)	38.0	Chemicals	1,728.46
Suspended solids (p.p.m.):		Utilities	3,375.68
Influent	300	Maintenance	2,072.45
Effluent	110	Truck operation	758.30
Reduction (%)	63.3	Industrial wastes survey	1,211.82
Chlorine:		Sewer system, maintenance	2,512.51
Total used (lb.)	11,250	Admin. and gen.	16,684.71
Residual (p.p.m.)	0.3	Authority, rental and misc.	51,275.00
Raw sludge:		Total	93,319.00
Amount (g.p.d.)	3,250	Revenue ($)	96,538.88
Total solids (%)	14.0	Profit ($)	3,219.88

1956, both financially and operationwise. It is believed that, with one digester operating properly and the other being cleaned, it will be possible to utilize the gas produced for heating the plant building next fall and winter. This will save a monthly gas bill of approximately $150.

Table I is a summary of operating data for the report year.

NOTES FROM A PLANT NEWSLETTER*

December, 1955

The average sewage flow treated during the month of November was 16.08 m.g.d. The raw sewage suspended solids and B.O.D. were 234 p.p.m. and 120 p.p.m., respectively. The primary tanks removed an average of 45 per cent of the B.O.D. and 65.4 per cent of the suspended solids from the sewage. In sludge digestion, 3,832,000 cu. ft. of gas were produced; approximately 72 per cent was utilized in the plant for heating purposes.

ORSANCO is to secure measurements of radioactivity at selected points in the 981 mile length of the Ohio River and at the confluence of principal tributaries.

In October the Abbe Observatory weather station (Cincinnati, Ohio) recorded a total precipitation of 4.70 in. The average monthly temperature was 56.8° F. The high was 79° F. on the 4th and 23rd and the low was 33° F. on the 25th. The cold night of October 24–25 brought a general frost which terminated a 199 day growing season in the Cincinnati area.

The change of operation procedure (at the pump building) permitting the flooding of the bar-screen chamber shows promise of several favorable factors as follows: (a) a more continuous flow through the treatment plant; (b) elimination of operation of second pump during dry-weather flow periods; (c) screening with one comminutor; (d) lower pumping power demand; (e) reduction of pump operation head with subsequent increase in efficiency of pump operation; and (f) more efficient sampling of raw sewage.

The operation of the Delta Avenue Pumping Station now adds about 2.8 m.g.d. of sewage to the Little Miami plant load.

As recorded at Abbe Observatory, the average monthly temperature in November was 41.6° F. The high for the month was 79° F. on the 13th and the low was 9° F. on the 28th. Total precipitation for the month was 4.22 in. Excessive rainfall was recorded in thunderstorms on the 15th and 16th.

November marked the second month of operation of the No. 1 primary settling tank as an elutriation tank. Sludge from the primary digesters was discharged daily to this tank with raw sewage used as a wash water for the elutriation. During November, a total of 531,000 lb. of dry solids were added to this tank from the primary digesters. In this same period 387,000 lb. of solids were removed and processed on the vacuum filters. An analysis of the discharge from the tank showed 189,000 lb. of solids were discharged to the effluent weirs. The average solids concentration of the sludge removed from the digesters was 4.8 per cent and the average solids of the washed sludge process on the vacuum filter was 7.7 per cent.

During the week of December 5 to 9, the plant elutriation tanks were operated utilizing counter-current sludge wash under minimum flow and solids

* Extracted from the December, 1955 and January, 1956 issues of *The Settling Tank*, newsletter of the Little Miami sewage treatment works, Cincinnati, Ohio, edited by D. P. Backmeyer, Superintendent, and A. E. Schwer, Assistant Superintendent.

loading conditions. A review of this operation indicates very poor concentration of the sludge solids in the elutriation tanks. In four days of operation, approximately 78 per cent of the input solids were retained in the system with a loss of 22 per cent over the effluent weirs. The average concentration of the sludge solids added to the system was 7.7 per cent. The sludge removed for processing on the vacuum filters averaged less than 6 per cent total solids. The sludge total alkalinity concentration was reduced from 800 p.p.m. to 150 p.p.m. Based on influent flow rates, the theoretical retention time was 12.7 hr. in the primary wash tank and 13.8 hr. in the secondary tank. Design data for maximum loading conditions indicates a holding time of 3.4 hr.

January, 1956

The total raw sewage flow treated in December was 481,000,000 gal. Of this volume, the Delta Avenue pumping station probably contributed about 60,000,000 gal. If 0.22 lb. of suspended solids is considered a per capita equivalent, the daily average solids loading of 35,800 lb. would represent a contributing population of 162,500. The average B.O.D. of the raw sewage is approximately 52 per cent of the suspended solids. Using a per capita equivalent of 0.17 lb. the equivalent population is 108,000.

One comforting thing about being called a procrastinator is that you'll probably never get around to looking up its meaning.

Safety colors for industry have been recognized for years. They provide an orderly, coordinated standard of practice for any plant in any industry. Color enables the worker to memorize all hazards and protective devices put there to keep him alert and prepared for any emergency.

Treatment efficiencies for the Little Miami flocculation—primary tanks in December are indicated by the B.O.D. removal of 45.1 per cent and suspended solids removal of 60.5 per cent. The raw sewage had an average B.O.D. of 142 p.p.m. and suspended solids of 276 p.p.m.

A total of 431 persons visited the Little Miami plant in 1955. This number was comprised chiefly of local engineers and school groups. Included were 14 persons from 10 foreign countries.

As an average for 1955, the ferric chloride feed rate for conditioning elutriated digested sludge was 5.05 per cent on a dry solids basis. At an average cost (anhydrous basis) for ferric chloride of $4.05 per hundredweight the chemical cost per dry ton of solids dewatered was $4.09.

The great difference between the apparent B.O.D. and suspended solids concentration of the raw sewage at Little Miami is difficult to justify. As an average for December, the B.O.D. is about one-half the suspended solids concentration. The solids removed as raw sludge do not have unusually low volatile content. In a 30-day period the average volatile content of the sludge was 69.78 per cent. The low percentage was 65.96 and the high was 74.01.

In the period January 1 to 17, all the raw sludge was pumped to one of the four sludge digesters as the first step in two-stage digestion. The computed displacement time in the primary digester was 13 days with a volatile solids feeding rate of 7.5 lb. per cubic foot of digester capacity per month. The gas yield in the primary digester was 84.7 per cent of the total gas produced. The average daily production rate was 1.8 cu. ft. per cubic foot of digester tank in use. The tank contents were mechanically circulated 12 hr. per day to maintain a temperature of 91° F.

In reviewing the 1955 solids removal quantities it is noted that 4,480 tons of dry solids were removed as raw sludge and that 3,121 tons of solids were re-

moved as suspended solids, the latter being based on hourly samples of the raw sewage not contaminated with recycled plant process liquors.

The following is from the summary of the report on chlorination at the Little Miami Sewage Works:

Chlorine residuals (0 to 0.03 p.p.m.) were obtained in the plant effluent when chlorinating in the morning at a rate of 30 lb. per hour (5.8 p.p.m. dosage at 15 m.g.d.). When chlorinating at 15 lb. per hour, the residuals in the plant effluent increased to .07 to 0.2 p.p.m. in the morning but in the afternoon the residuals were undetectable beyond the aeration channel.

Excellent coliform reductions were obtained when prechlorinating at 40 lb. per hour in the morning but reductions dropped off rapidly when the dosage rates were decreased or the flows increased from 15 to 30 m.g.d. The strength of the raw sewage increased markedly in the afternoon and this seriously affected the coliform reductions.

TIPS AND QUIPS

Gastistics

Gas produced at the Richmond, Ind., sewage treatment plant is valued at $1.60 per ton of garbage received. The cost of grinding the garbage is $1.06 per ton.

Obscure Paint

An inexpensive paint that can be brushed on window glass to obscure an outsider's view has been developed by research engineers at New York University. Unlike other window paints, this new barrier to prying eyes permits 80 per cent of the natural daylight to enter.

Utility Lantern

An ingenious utility lantern utilizing a battery which itself is the battery case has been introduced by the Burgess Battery Co. The lantern features an adjustable sealed beam spotlight that can be tilted up or down 135°. An adjustable red warning light, flashing once a second, is mounted to the rear of the spotlight. Both lights can be operated independently.

Engineered for the lantern is a new two-in-one power pack, consisting of two 6-v. lantern batteries wired in parallel. It is reported that the useful life of this battery is 2½ to 4 times that of a conventional single 6-v. lantern battery.

The new lantern was designed to provide a light weight compact emergency light for homes, offices, industry, and civil defense. Initially it is being marketed with and without the red flashing light. Retail prices reported are $11.95 and $9.40 respectively, in-

cluding the battery which has a replacement price of $2.45.

Under-Water Disposal

A new method of combustion under water, which disposes of pulp mill wastes efficiently and yields low cost steam, is expected to be adaptable to other organic wastes. This might be the answer to sludge disposal problems at municipal sewage treatment plants.

Drip-proof

Polyethylene resin can be utilized for a non-wetted sleeve around the necks of reagent bottles that prevents drip and avoids hazard from dangerous substances running down the sides of bottles. Try some today in your lab.

Alert Today—Alive Tomorrow

The New England Sewage and Industrial Wastes Assn., through its Safety Committee, chairmanned by LeRoy W. Van Kleeck, has prepared a sewage works safety placard as a service to the profession and the individual treatment plant operator. The card measures 13 in. by 10½ in. and is printed on heavy white cardboard. It's size makes for convenient display wherever operating personnel need to be reminded of good safety practices.

The text of the cards features the following pertinent information:

Safety in Sewers

1. Avoid all open lights and sparks around manholes and in sewers. Use explosion-proof safety electric lights.
2. Employ a safety belt when entering any manhole or pit deeper than 10 ft. and have two men stand by.
3. Test deep manholes or pits for combustible gases, oxygen deficiency, carbon monoxide and hydrogen sulfide. Observe any foreign odor or irritation to the eyes.
4. If any of the tests in (3) is positive, thoroughly ventilate structure with compressed air or a portable blower and repeat tests.
5. In emergencies, when a known hazard exists or tests in (3) have not been made, wear a hose mask or compressed air demand-type mask and avoid all sources of ignition.

Safety in Sewage Pumping Stations and Treatment Plants

1. Guard against falls.
2. Handle objects safely.
3. Provide guards for openings to structures below grade and for moving parts of machinery.
4. Do not connect potable water piping with sewage or sludge pipes.
5. Where chlorine is used follow instructions in "Chlorine Manual" available from Chlorine Institute, 50 East 41st St., New York 17, New York.
6. Keep sludge digesters full when in operation and maintain sludge gas collection system under positive pressure. Check periodically for sludge gas leaks with combustible gas indicator.
7. Post at telephone the emergency numbers of the fire department, police, ambulance service and several doctors.

General Personal Precautions

1. Do not smoke in any structure where combustible gases may be present (sewers, gas collection galleries, etc.)
2. Wash hands (with hot water and soap) after work and before smoking or eating.
3. Administer prompt first-aid to all minor cuts or wounds.
4. Have yearly booster shots for typhoid and tetanus.
5. Be familiar with Nielson arm-lift back-pressure method of artificial respiration.
6. Employ good housekeeping.
7. Have available the Federation's Manual of Practice No. 1.

Arrangements have been made to distribute single copies of the placard gratis to every sewage treatment plant in New England through the district sanitary engineers of the various state departments of health. Copies of the placard are available to Member Associations and individual members at a cost of $0.30 postpaid. Special quantity prices will be quoted on request. Address inquiries to Henry F. Munroe, Secretary-Treasurer, New England Sewage and Industrial Wastes Assn., 75 Pine Ave., Cranston 10, R. I.

Sewage Lagoons

It is reported that there are at least 156 sewage lagoons in operation in the United States.

Folding Steel Legs

Versatile folding steel legs and standard 2-in. by 4-in. lumber (Figure 1) can

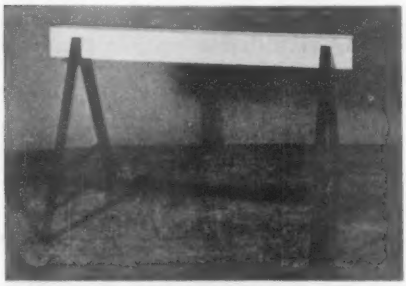

FIGURE 1.—Folding steel legs that are quickly applied or removed.

quickly make a carpenter's saw horse, low scaffolding, temporary work benches or a barricade. The legs are fabricated from ⅛-in. angle iron and reported to be capable of supporting 500 to 1,000 lb. in pairs, depending on leg height. The upper "gripper-claw" portion of the leg bites into standard 2-in. by 4-in. lumber when the legs are spread open. Protruding teeth hold the wood in place and alignment flanges maintain the position of the wood in relation to the legs.

Literature may be obtained from Weldon Products, 1451 East Nine Mile Road, Hazel Park (Detroit), Mich.

Power Brush Cutter

A portable brush cutter powered by a knapsack-type 2.8 h.p. gasoline engine slices through fine weeds and scrub trees. Cutting is done by a 10-in. diameter toothed blade. The light weight (39 lb.) unit is balanced for easy effortless operation. As with all power tools the cutter must be carefully handled.

Manufacturer is the Southworth Machine Co., Portland, Me.

More About Protective Coatings

When preparing the protective coating maintenance program for a sewage treatment plant or lift station, handbooks, catalogs and other informative material published by paint and coating manufacturers, should not be overlooked.

The Steel Structures Painting Manuals, Nos. 1 and 2, are excellent guides. Copies may be obtained from: Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh, Pa.

Tropical Paint and Oil Co., Cleveland, Ohio, has a comprehensive painting guide in the form of a publication entitled "Recommended Maintenance Painting Systems for Sewage Treatment Plants."

Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif., recently released an illustrated catalog describing a method of controlling rust and corrosion.

Before painting check the literature, consult the technical personnel of the various paint manufacturers, or have a talk with your regular paint supplier.

Reviews and Abstracts*

Factors Affecting the Growth of Some Fungi Associated with Sewage Purification. By H. A. Painter. *Jour. of General Microbiology,* 10, 1–3, 177 (1954).

Various aspects of the nutrition of four fungi which commonly inhabit percolating filters treating sewage have been studied. Predominating fungus, *Sepedonium n. sp.,* required organic sources of nitrogen while *Fusarium aqueductum, Geotrichum sp.,* and *Trichosporon cutaneum* were able to utilize ammonium salts; *F. aqueductum* was also able to utilize nitrate. For optimum growth *T. cutaneum* required thiamine and *Sepedonium sp.* required thiamine and biotin, while *Geotrichum sp.* and *F. aqueductum* needed no external supply of vitamins. The pH range for optimum growth was narrow (pH 7 to 8.5) for *Sepedonium sp.* while the ranges for the other fungi were much wider (pH 3 to 9).

Zinc, calcium, manganese and probably iron and copper were required by *Sepedonium sp.,* which was the only one of the four fungi inhibited by concentrations of zinc above the optimum in media partially deficient in other elements. Manganese, iron or copper when added with zinc counteracted the inhibitory action, while calcium increased it. H. Heukelekian

Experiments on the Methane Bacteria in Sludge. By R. L. Mylroie and R. E. Hungate. *Canadian Jour. of Microbiology,* 1, 1, 55 (1954).

An attempt was made to isolate and count in agar dilution cultures, methane bacteria directly from the natural source without preliminary enrichment. A solution containing the necessary mineral salts and sodium bicarbonate was sterilized and kept under an atmosphere of 80 per cent hydrogen and 20 per cent carbon dioxide. Cysteine or a small amount of palladium chloride was used as a catalyst to reduce the oxidation-reduction potential. Growth under these conditions was accompanied by methane production and the organism was identified as *Methane bacterium formicicum.* A suitable reducing agent for this organism was 0.01 and 0.015 per cent sodium sulfide; concentrations of 0.005 or 0.02 per cent were not. Details of final procedure adopted are given.

Morphological characteristics of *Methane bacterium formicicum* were determined. The optimum temperature was 38° and 45° C. with no growth at 55° C. The medium was adjusted to different pH values and the time required to obtain growths was determined. No growth was obtained at pH 6.0 or below and at pH 8.0 or above 38° C. The failure of growth above 7.8 was attributed to the lack of carbon dioxide. The addition to the medium of yeast extract and sludge liquor did not decrease the time for appearance of colonies. The addition of ethanol, methanol, acetate, proprionate, butyrate, lactate, and glucose to the basal medium did not produce more methane than the controls. Formate was the only exception. Apparently this organism utilizes only hydrogen and carbon dioxide and formate.

Attempts were made to isolate a methane organism from sludge capable of utilizing acetate without success.

The occurrence of *M. formicicum* in large numbers in sludge indicated that it must be of importance in sludge digestion. Formate when added to sludge is rapidly converted to methane and carbon dioxide.

H. Heukelekian

Sewage Purification for Sutton Coldfield's Housing Scheme. *Surveyor,* 114, 1155 (1955).

Description of a sewage treatment plant designed for a dry weather flow of 360,-

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N.W., Washington 16, D. C.

000 g.p.d. (Imp.). Four standard-rate trickling filters, primary and secondary sedimentation, and separate two-stage sludge digestion are provided. The plans allow for eventual expansion to three times the present capacity. M. C. RAND

Fundamental Concepts of Rectangular Settling Tanks. By A. C. INGERSOLL, J. E. MCKEE, AND N. H. BROOKS. *Proc. Amer. Soc. Civil Eng.*, **81**, Sep. No. 590 (Jan., 1955).

The authors have investigated fundamental theories of sedimentation and devote considerable text to the derivation of equations for computing ideal and actual efficiencies and the effects of scouring due to turbulent eddies. A new rational measure called the "overflow efficiency" is developed theoretically.

The results of several studies on ways to reduce turbulence, the effects of inlet and outlet structures and theoretical means for obtaining denser sludges in settling tanks led to the authors' recommendations for further research on tanks with conventional surface overflow rates, high ratios of length to width and the use of inclined baffles to minimize scour and to improve the thickening of sludge. W. A. HASFURTHER

Symposium on Stream Pollution Problems:

1. **Biochemical Behavior of Synthetic Detergents.** By C. N. SAWYER, R. H. BOGAN, AND J. R. SIMPSON. *Ind. Eng. Chem.*, **48**, 236 (1956).

The anionic and nonionic detergents used today appear to be subject to biological attack, but they vary greatly in their susceptibility even among a given class. This variation is believed to be largely related to difference in chemical structure and molecular size. Adaptation or acclimation of biological microorganisms is important in evaluating their behavior. Tetrapropylene benzene sulfonate, the most important detergent in terms of current-day use, is extremely resistant to oxidation. A half-life of about 16 days in river water under summer conditions is indicated.

2. **Detergents in Water Supplies.** By J. C. VAUGHN AND R. F. FALKENTHAL. *Ind. Eng. Chem.*, **48**, 241 (1956).

Water plant operators are having difficulty with taste and odor, foam on settling basins and in the finished water, and with the processes of coagulation and sedimentation.

3. **Conditions in Activated Sludge Process during Frothing.** By G. P. EDWARDS AND M. E. GINN. *Ind. Eng. Chem.*, **48**, 246 (1956).

The authors recommend that anionic detergents be reported in terms of milliequivalents per liter in order to have a proper comparison of results given by various experimenters.

During an aeration cycle in an activated sludge plant, much of the detergent is rapidly adsorbed by the sludge, while the surface tension of the liquor increases gradually. Under conditions of laboratory experiments frothing seems to be independent of surface tension.

No explanation of the belated appearance of froth in the aeration tank is given by the observations made to date.

4. **Radioactive Fallout in Surface Waters.** By L. R. SETTER AND A. S. GOLDIN. *Ind. Eng. Chem.*, **48**, 251 (1956).

This article reports on the measurements of radioactive fallout in the Cincinnati, Ohio, area for a period of two years. The fate of the radioactivity in surface waters is discussed.

5. **Biochemical Oxidation Characteristics of Stream-Pollutant Organics.** By M. B. ETTINGER. *Ind. Eng. Chem.*, **48**, 256 (1956).

After studying a variety of normal and new synthetic compounds, the authors conclude that there can be a tremendous variation in the rate at which a specific chemical compound undergoes biological attack. Variables such as seed, temperature, concentration, mineral nutrients and pH have been assayed.

Different chemical compounds show a wide range of resistance to biochemical attack. A limited laboratory investigation may fail to reveal the susceptibility of a compound to biological destruction.

Stream pollutants cannot be evaluated satisfactorily in terms of B.O.D. alone. A chemical resistant to biological destruction may be capable of doing much more damage than mere depletion of oxygen in a stream.

6. Biological Oxidation Parameter Applied to Industrial Wastes. By E. J. Mills and V. T. Stack. *Ind. Eng. Chem.*, 48, 260 (1956).

Excellent evidence is presented to indicate the importance of a properly acclimated seed in a B.O.D. test. If the acclimated seed is not available then the B.O.D. readings should be taken over a much longer period. Even if acclimated seed is used, the use of complete B.O.D. curves is highly recommended in order to better understand the nature of the biochemical reactions.

The paper reports on the B.O.D. values for acrylonitril, ethylene glycol, carbitol and acetone.

7. Persistance of Oily Wastes in Polluted Water Under Aerobic Conditions. Motor Oil Class of Hydrocarbons. By F. J. Ludzack and D. Kinkead. *Ind. Eng. Chem.*, 48, 263 (1956).

Organisms capable of biochemical destruction of oily waste in water are abundant in nature. This work reports the effect of common variables related to stream pollution on the rate of oil destruction by microorganisms. Oxidation of oil was not observed at low temperatures; at summer temperatures, the half-life of the oil was approximately one week.

8. Drinking Water Taste and Odor Correlation with Organic Chemical Content. By F. M. Middleton, W. Grant, and A. A. Rosen. *Ind. Eng. Chem.*, 48, 268 (1956).

A large variety of compounds in organic wastes have caused serious tastes and odors in the drinking water of a municipal supply. A system of concentrating the organic wastes and identifying them is given.

9. Determination of High Boiling Paraffin Hydrocarbons in Polluted Water. By F. J. Ludzack and C. E. Whitfield. *Anal. Chem.*, 28, 157 (1956).

By using a continuous liquid-liquid extraction of suspended oil from water samples, a quantitative recovery of petroleum fractions was achieved. Carbon tetrachloride was dropped through the water with air used for agitation. The fractions of oil were separated on a chromatographic column and identified with an infrared spectrophotometer.

10. Determination of Anionic Detergents in Surface Waters and Sewage with Methyl Green. By W. A. Moore and R. A. Kolbeson. *Anal. Chem.*, 28, 161 (1956).

A colorimetric procedure is given for the determination of anionic detergents at low concentration. Methyl green is added to a sample at pH 2.5 and the dye-detergent complex extracted with benzene. The benzene fraction is assayed in a spectrophotometer at 615 mμ.

There is no interference from sulfate, chloride, sulfite and phosphate while slight interference is given by thiocyanate, nitrate and nitrite ions.

11. Determination of Low Chemical Oxygen Demands of Surface Waters by Dichromate Oxidation. By W. A. Moore and W. W. Walker. *Anal. Chem.*, 28, 164 (1956).

The authors have modified their earlier technique appearing in the 10th edition of *Standard Methods* to permit the analysis of samples of stream water in the low range of 5 to 50 mg. per liter of C.O.D. Instead of the dichromate solution of 0.25 N, a solution of 0.025 N dichromate is used on the dilute samples. The ratio of concentrated sulfuric acid to the sample plus dichromate solution is maintained.

Special precautions are required for preventing chance contamination from contaminated distilled water or laboratory air. Special corrections for chlorides in the presence of the silver sulfate catalyst are necessary. R. S. Ingols

Fission Products From Nuclear Reactors. By James G. Terrill, Jr., Dade W. Moeller, and Samuel C. Ingraham, II. *Proc. Amer. Soc. Civil Eng.*, 81, Sep. No. 643 (Mar., 1955).

This paper is pertinent to those who have had background in radioactive reactions. The text discusses fission yields, production of electric energy from fission products, decay and rate of decay of these products, and removal and disposition of spent fuels from reactors. It is considered that a number of atomic energy power

plants will be built and means for computing fission wastes and volumes of water coincident with their removal are given. Tables and illustrations show fission yields, activity, residual weights of fission products, and relations of time and activity, when removed and at specified periods after removal of fission products from reactors.

W. A. HASFURTHER

BOOKS, REPORTS, AND PAMPHLETS

Water Resources and Power. Vol. 1. Commission on Organization of the Executive Branch of the Government. Supt. of Doc., U. S. Govt. Printing Office, Washington, D. C. 124 pp. Price $0.50 (1955).

A comprehensive and readable presentation of the recommendations prepared by the Task Force on Water Resources and Power.

Water Resources and Power. Vol. 2. Commission on Organization of the Executive Branch of the Government, Supt. of Doc., U. S. Govt. Printing Office, Washington, D. C. 94 pp. Price, $0.35 (1955).

This volume presents the individual statements of the several commissioners.

Biennial Report 1953 and 1954. National Bureau of Standards. Miscellaneous Publication 213. 162 pp. Price, $0.60, from Supt. of Doc., Govt. Printing Office, Washington 25, D. C. (1955).

Report on the Investigation of Travel of Pollution. Publ. No. 11, State Water Pollution Control Board, Sacramento, Calif. 218 pp. (1955).

Reports on field studies of the artificial recharge of aquifers with reclaimed sewage and other wastes to obtain data on the extent and rate of travel of pollution, the economics of recharge wells and feasible methods of operation.

Municipal Public Works Cost Accounting. Amer. Pub. Works Assn., 1313 East 60th St., Chicago, Ill. 97 pp. Price, $3.00 (1955).

The Susquehanna River Drainage Basin. New York State Water Poll. Control Board, Albany, N. Y. 30 pp., plus tables, graphs and maps (1955).

Report on the recommended classifications and assignment of standards of water quality and purity for this basin.

The Lake Champlain Drainage Basin. New York State Water Poll. Control Board, Albany, N. Y. 29 pp., plus tables, graphs and maps (1955).

Report on the recommended classifications and assignment of standards of water quality and purity for this basin.

Bulk Materials Handling with Overhead Traveling Bucket Cranes. Blaw-Knox Co., Pittsburgh, Pa. 8 pp. (1955).

Stream Sanitation in Florida. By D. B. SMITH, J. W. WAKEFIELD, H. A. BEVIS, AND E. B. PHELPS. Florida Engineering Series No. 1, College of Engineering, University of Florida, Gainesville, Fla. 149 pp. Price, $1.10.

A comprehensive survey of the water resources of Florida with a detailed analysis and listing of the sources of pollution in each of the principal watershed areas.

Mississippi River Water Pollution Investigation. St. Louis Metropolitan Area. Bi-State Development Agency, 915 Olive St., St. Louis, Mo. 144 pp., plus appendices (1955).

Report on a survey made jointly by the states of Illinois and Missouri and the U. S. Public Health Service.

A Biological Survey of the Peace River, Florida. By ELLIS LANQUIST. Florida State Board of Health, Jacksonville, Fla. 75 pp., plus illus., mimeo. (1955).

This report is a supplement to the Peace and Alafia rivers stream sanitation studies undertaken by the Florida State Board of Health in 1950–53.

A Symposium on Supplemental Irrigation. Interstate Commission on the Potomac River Basin, 203 Transportation Building, Washington 6, D. C. (1955).

A compendium of opinion as expressed in speeches and discussions at a meeting held in Winchester, Va. (May, 1955).

Circular Collectors

Types for every waste treatment problem

- DESIGNED FOR EFFICIENT LONG-TERM OPERATION
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This pier-supported collector is designed for circular tanks. The rotating bridge acts as the lever arm rotating a sturdy center cage which carries the collector arms. Rotational force is provided by a two-wheeled, rubber tired tractor unit running on the rim (or effluent weir wall of the tank). Drive unit is simple, easily accessible, and not affected by snow or ice.

SUSPENDED COLLECTORS are used where a simple bridge can span the tank diameter. In this case, the complete motor and drive assembly, together with the drive tube and collector arms, are suspended from the bridge.

WRITE FOR BULLETIN 9W65

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WRITE FOR BULLETIN 10169

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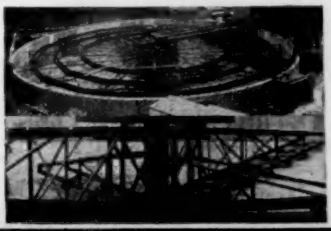

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Proceedings of Member Associations

NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

The 1955 Annual Convention of the North Dakota Water and Sewage Works Conference was held September 28–30, 1955, at the Plainsman Hotel, Williston, N. Dak. The new oil city played host to 120 delegates and about 25 ladies.

Papers of interest to sewage and industrial waste personnel included:

"Recreational Developments Planned for Garrison Reservoir," by R. T. Lierboe, Chief of Relocations and Reservoir Development Branch, Corps of Engineers, Riverdale.

"Oil Field Waste Disposal," by Dr. Wilson Laird, State Geologist, Grand Forks.

"Maintenance and Operation of Sanitary Sewers and Sewage Pumping Stations," by L. W. Veigel, Consulting Engineer, Dickinson.

"Lagoon Study Reviews," by Bill Davis, Sanitary Engineer, USPHS, Cincinnati, Ohio.

A panel discussion, moderated by Charles E. Carl, South Dakota State Sanitary Engineer, Pierre, S. Dak., dealt with the topic "If My Community Were to Build Another Sewage Lagoon." Panel members were: Ted Kritsky, Butte; Leonard Sanford, Watford City; Marvin Allum, State Health Department, Pierre, S. Dak.; and Joe Schaeffer, Chief Sanitary Engineer, Province of Saskatchewan, Canada.

(*Continued on page 240a*)

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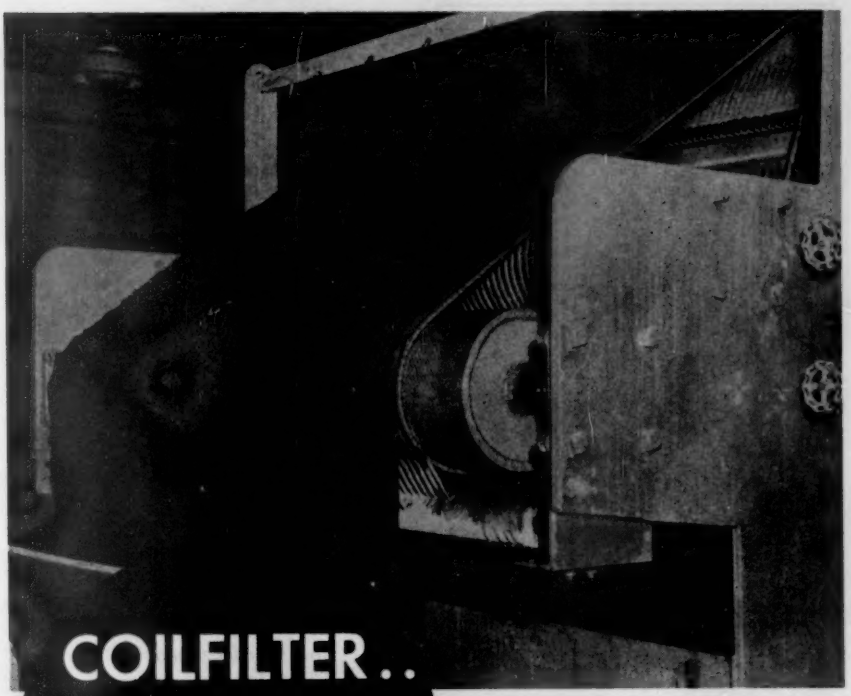

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Another panel discussion was devoted to the topic "Public Works Record Keeping Methods." Participating were Arnold T. Livdahl, City Auditor, Mandan; E. J. Booth, City Engineer, Bismarck; and H. H. Behlmer, Superintendent of Water Works, Fargo.

The Conference concluded with two forum discussions on water, sewage and public works problems. One was devoted to the problems of communities with populations in excess of 2,000. The second discussed the problems of smaller communities.

Officers elected to serve during 1955–6 were as follows:

President: Edwin Ostlie, Grand Forks.
Vice-President: Erik D. Peterson, Jamestown.
Secretary-Treasurer: J. H. Svore, Bismarck.

JEROME H. SVORE,
Secretary-Treasurer

(*Continued on page 242a*)

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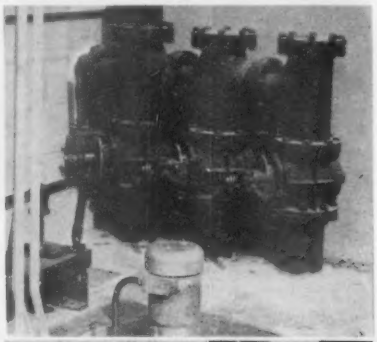
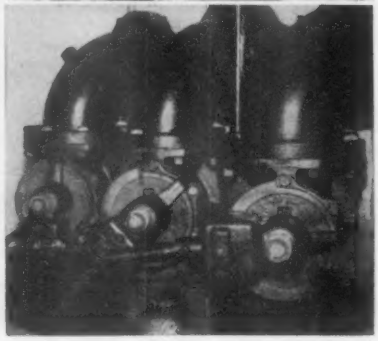
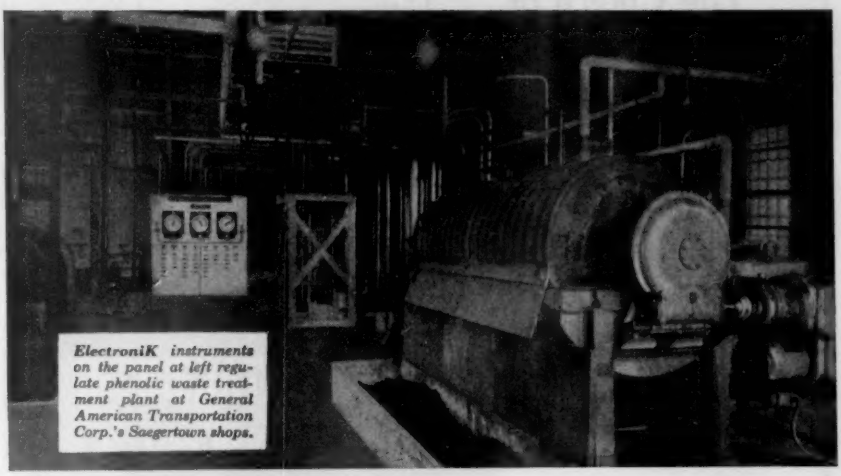




You can treat toxic wastes continuously under control of *ElectroniK* instruments



ElectroniK instruments on the panel at left regulate phenolic waste treatment plant at General American Transportation Corp.'s Saegertown shops.

ARE YOUR wastes toxic? The economical way to convert them to safe effluent is through continuous treatment. And the effective way to operate a continuous system is to use *ElectroniK* instruments.

Here's how it works at the Saegertown, Pa. plant of General American Transportation Corporation. Wash waters from railway tank car cleaning operations often contain phenol and other toxic ingredients, which must be removed before discharge to a nearby river. A continuous system treats some 50,000 gallons of waste daily, by a combination of adsorption, flotation, flocculation and biological oxidation.

Several *ElectroniK* pH controllers play important parts in the system. These instruments control the flow of acid or alkaline reagent to maintain exactly the right pH for the treatment processes. Their close, sensitive control enables the system to reduce the phenol content to minimum approved levels in the final effluent. Moreover, this particular treatment plant is so thoroughly automatic that a single operator can handle the complete supervisory job.

Your nearby Honeywell sales engineer will be glad to discuss how modern *ElectroniK* instrumentation can cut costs in your own water or waste treating processes. Call him today for a consultation . . . he's as near as your phone.

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● **REFERENCE DATA: Write for Catalog 1551, "pH and Conductivity Instrumentation."**

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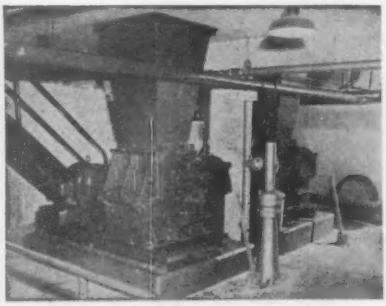

View of twin Sewage Shredder Installation

Gruendler patented Sewage Screening Shredders are nationally recognized by public sewage works for their efficient method of disintegration of wastes including rag stock, for uninterrupted flow.

Flow control through wastes disintegration

CATALOG – S.G.10 mailed without obligation, containing diagrams for installation, types and sizes of Sewage Shredders, Garbage Grinders, Dry Sludge Shredders, Refuse & Compost Grinders.

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MONTANA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 12th Annual Meeting of the Montana Sewage and Industrial Wastes Association was held on April 5, 1956 at Livingston, Mont. The Murray Hotel served as headquarters and the Elk's Temple as meeting place. Registration totaled 48.

Verne Reed, City Engineer of Livingston, presided during the meeting in the absence of M. F. Dixon of Billings, Mont., Chairman of the Association. Mayor Walter Anderson of Livingston welcomed the group at the opening meeting. Emil Jensen, Federation Director from the Pacific Northwest and member of the Federation Executive Committee, was the Federation's representative at the meeting.

The morning session featured a stream pollution symposium.

At the afternoon session a paper on industrial hygiene in sewerage works was presented by B. F. Wake, Industrial Hygiene Engineer, State Board of Health, Helena, Mont.

A panel discussion, moderated by Verne Reed, was held on the subject of "Sewer System Design and Maintenance." Those participating were: Rodney Preator, Sanitary Engineer, Morrison-Maierle Inc., Helena, Mont.; Kurt Wiel, City Engineer, Miles City, Mont.; Pette Breysee, Public Health Engineer, State Board of Health, Helena, Mont.; and Claude Eyer, City Engineer, Glendive, Mont.

At the business meeting, the following officers were elected for 1956–57:

Chairman: Verne Reed, Livingston.
Vice-Chairman: Claude Eyer, Glendive.
FSIWA Director: D. H. Denman, Lovell, Wyo.
Secretary-Treasurer: Harvey W. Taylor, Helena.

HARVEY W. TAYLOR,
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For this Hempstead plant, we furnished four Morse Boulger Mechanically Stoked Furnaces for handling up to 700 tons of refuse per 24 hours. Waste heat boilers recover much of the heat and provide steam for two 1000 kw. turbo-generators. Our engineers also furnished the crane charging equipment, stacks, fly ash removal unit and ash removal conveyor.

What we did to help in this Hempstead project we can do to help you...working with your sanitation engineer or your consulting engineer. The point to keep in mind is that your community, too, can have clean, efficient, nuisance-free refuse disposal in a modern incineration plant such as this Morse Boulger plant.

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Equipment and Supply Lines

Shredders and Grinders—Ruggedly built screenings and dry sludge shredders are described in Bulletin SG10. Garbage grinders for private and municipal use are also illustrated.—Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis 6, Mo.

Plastic Fabrications and Pipe—An 8-page bulletin outlines use and characteristics of Type I polyvinyl chloride in fabrication of exhaust systems and processing equipment.—Atlas Mineral Products Co., Mertztown, Pa.

Uniclosed Electric Motors—Colorful 12-page illustrated Booklet 1856 pictures the construction features of this fully protected electric motor. Cut-open views of the transverse lubrication and splash-proof ventilation systems are included—U. S. Electric Motors Inc., Box 2058, Los Angeles 54, Calif.

Cutting Tools—Practical information on the use of cemented carbide cutting tools is furnished in the eighth edition of a methods manual on carbide metal tools.—Allegheny Ludlum Steel Corp., Pittsburgh 22, Pa.

Temperature Controller—Brochure MC–121 describes a new remote bulb heavy duty temperature controller.—Fenwal Inc., Ashland, Mass.

Glass Products—Quartz and glass precision-bore tubing of various cross sections for equipment or laboratory use are described in Catalog 80–20.—Fischer & Porter Co., 379 Jacksonville Road, Hatboro, Pa.

Corrosion-Resistant Coatings—A recently announced neoprene based coating material can be easily brushed on metal surfaces to provide a coating resistant to salts, alkalies and most acid concentrations.—Corrosion Control Co., Inc., 516 Fifth Ave., New York 36, N. Y.

Pneumatic Flow Meters—Colored Bulletin 285–G2A describes flow metering requirements for efficient operation of water and sewage treatment plants.—Builders-Providence Inc., 345 Harris Ave., Providence, R. I.

Grating and Treads—Bulletin No. 2486 describes types, sizes, load characteristics and uses of electroforged steel and interlocked aluminum grating.—Blaw-Knox Co., Farmers Bank Building, Pittsburgh 38, Pa.

Silica Activator—Bulletin 63–M1 describes a new silica activator for continuous processing of activated silica sols. Provision is made for selective use of various activating reagents.—Omega Machine Co., 345 Harris Ave., Providence, R. I.

Guillotine Pipe Saw—Cast iron and steel pipe up to 16 in. in diameter can be cut quickly in a 3-ft. wide trench with a new large guillotine pipe saw.—E. H. Wachs Co., 1525 North Dayton St., Chicago 22, Ill.

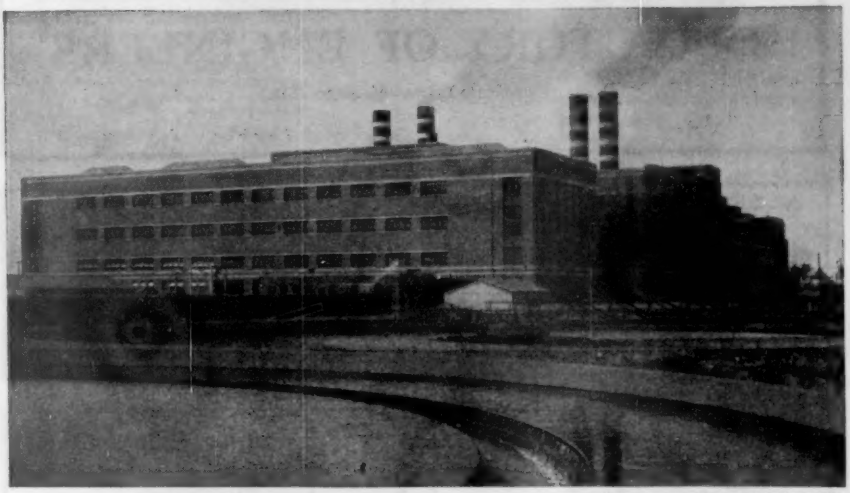
Quiet Pump—New, self-priming centrifugal pump with top capacity of 150 g.p.m. is available for dewatering operations where noise level must be low. This portable pump can be throttled to reduce noise and is equipped with a muffler.—Homelite, Riverdale Ave., Port Chester, N. Y.

Industrial Liquids Pump—A horizontal, single-stage centrifugal pump with a diverging type impeller is described in Bulletin Form 7325 for handling pulp and paper stock and liquids containing a high percentage of solids, or for use where large amounts of air are required in the pump suction.—Ingersoll-Rand Co., 11 Broadway, New York 4, N. Y.

Clarifiers and Thickeners—Graphically illustrated 16-page Bulletin W–800B–S–6000B presents design requirements of clarifiers and thickeners.—Infilco Inc., Tucson, Ariz.

Turbo-Dryers—Closed circuit turbo-dryers for continuous drying, cooling or subliming materials are described in Bulletin 5507.—Wyssmont Co., Inc., 42–09 27th St., Long Island City 1, N. Y.

The Chicago Sewage Disposal System



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There's good reason why the Metropolitan Sanitary District of Greater Chicago should be so highly honored. For its Sewage Disposal System, constructed at a cost of many millions of dollars, is the largest of its kind anywhere in the world. And its construction involved exceptional achievements—such as the reversal of flow of the Chicago River, to prevent pollution of Lake Michigan, which is Chicago's fresh water source.

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(Continued through page 251a)

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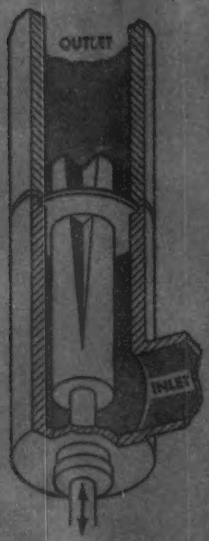

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